SCIENTIFIC AGRICULTURE

Vol. X. JUNE, 1930 No. 10

# THE BIONOMICS OF THE WHITE TRIANGLE LEAF-ROLLER, *CACOECIA PERSICANA* FITCH.

F. C. GILLIATT *

*Dominion Entomological Laboratory, Annapolis Royal, N. S.*

[Received for publication April 12, 1930].

In recent years the fruit growers of the Annapolis Valley, Nova Scotia, have suffered serious losses from a group of insects belonging to the family Tortricidae, the larvae of which feed upon and produce various types of side injury to the fruit.

In 1926, there was started a life history study of this group of insects. At that time the well-known Eye-spotted budmoth, *Spilonota ocellana* D. & S., was by far the most numerous and destructive species, but the study had not progressed far before it became apparent that several other species were involved which in the aggregate were responsible for considerable losses. One of the most important of these lesser orchard insect pests was *Cacoecia persicana* Fitch, for which we suggest the following common name, the White Triangle Leaf-roller. The life history of this latter species has, therefore, been under observation since 1926, and although further details will probably be recorded, the investigation has progressed sufficiently to include at least the most salient points in its life history and form the subject matter of this paper.

## HISTORY AND SYNONOMY

The few published records referring to *Cacoecia persicana* Fitch are very brief. It was described as a new species by Asa Fitch (*1*) from New York State as the Peach Tortrix, *Craesia persicana*. This description is limited to a few colour markings of the adult and larva. The larva is referred to as secreting itself and feeding upon peach foliage. The species has been reported from Quebec province, Winn (*2*) as feeding on strawberry. Both Forbes (*3*) and Leonard (*4*) mention *Cacoecia persicana* Fitch as distributed over New York State, the larva feeding on various plants. The former author states that it is to be found from Maine to Manitoba. In the collection of Perrin (*5*) and Russell, from Nova Scotia, *Archips persicana* is found as number 5379 taken at Digby. This is probably the first record of its presence in Nova Scotia. This species, previous to 1926, has apparently not been reported as a pest of the apple; in that year we found the larvae feeding on both the foliage and the fruit.

The following excerpt on the synonomy of the species was published by Fernald (*6*) in 1882-83.

Genus *Ptycholoma* Steph. Ill. IV, 1834.

*P. persicana.*

*Craesia persicana* Fitch, N.Y. Ag. Rept. p. 357 (1856).

*Ditula? blandana* Clem. Proc. Ent. Soc. Ph. iii, p. 516 (1864).

*Assistant Entomologist.

*Lozotaenia fragariana* Pack. Guide, p. 335 (1869).
*Tortrix* (*Argyrotoxa*) *conigerana* Zell. Beitr. p. 21, pl. 8, fig. (1875).
Habitat—Maine, New Hampshire, Massachusetts, New York.
Food—Peach, Strawberry.

## Food Plants

In the Annapolis Valley in addition to apple the writer has observe the larvae feeding upon timothy, couch grass, strawberry, five-finger, butte cup, goldenrod, wild radish, sheep sorrel, daisy, lady's thumb, dock, dand lion, clover and a species of wild aster. At the time the larvae emerge fro their winter quarters the green vegetation available is limited, and the in pression obtained from field observations was that any plant likely to b growing beneath the trees in the orchard is more or less readily eaten. Th foregoing list of host plants, therefore, must not be considered complete. O the other hand, although these various plants beneath the trees are readi consumed when first emerging in the spring, later they are largely discarde for apple foliage.

The following feeding experiments were conducted in 1928 to dete mine to what extent larvae, after hibernation, would mature if fed exclusive on the above plants.

Table 1. *Development of larvae of C. persicana on various food plants.*

| Date started | Food plant | No. larvae | No. pupated | No. adults emerged | Remarks |
|---|---|---|---|---|---|
| May 1 | Couch Grass | 25 | 0 | 0 | Larvae fed and developed no mally until about May 15 the last one to die was June 20. |
| May 1 | Timothy | 25 | 0 | 0 | Same remarks as per couc Last larvae to die was June 26. |
| May 1 | Dock | 25 | 20 | 12 | Apparently normal develo ment. |
| May 1 | Dandelion | 25 | 11 | 7 | Apparently normal. |
| May 1 | Buttercup | 25 | 19 | 10 | " " |
| May 1 | Sorrel | 25 | 20 | 11 | " " |
| May 1 | Strawberry | 25 | 19 | 13 | " " |
| May 1 | Clover | 25 | 8 | 3 | Food not consumed readi Larvae undersized. |
| May 1 | Old apple leaves | 25 | 0 | 0 | At first a limited amount feeding, but soon refused t food. |
| May 1 | Fresh apple leaves | 25 | 22 | 18 | Apparently normal. |

At first the larvae fed readily on the timothy and couch blades in the feeding tests, but it was not long before the amount consumed became qu small. It should be mentioned in this connection that these grasses dr very quickly and although a fresh supply was added as often as time wo

permit, it nevertheless at times became dry and unattractive. In contrast to this, the other plants were always fresh. As the larvae fed to a limited extend on the old apple leaves when first emerging from their winter quarters, this was also included in the feeding experiment. There was very little feeding on these dead leaves under test.

The new generation of summer brood larvae is, also, to be found in limited numbers beneath the trees, feeding on various grasses and weeds. These larvae are without doubt those that spin down from the trees at hatching time, with the addition from time to time of others which from winds or other causes are dislodged from the trees. These larvae under observation appeared to develop equally as well as those feeding on apple foliage.

## Life-history

*Method of study.* At the insectary, larvae were reared individually in glass vials about 4.5 inches long by 1 inch in diameter. The opening was covered with a piece of thin cotton held in place by a small rubber band. The food consisted of apple leaves which kept in a fresh condition in the vials from one to three days, depending upon the weather. The larvae on the whole were contented, with normal development in most instances. With close attention the dates of each moult were readily obtained.

The breeding cages used were flower pots set with a small apple seedling. In 1927, lantern globes were placed over the seedlings to confine the adults. For several reasons these globe cages were not entirely satisfactory, and in 1928 a strip of wire screening about ten inches wide was rolled to form a tube about four to five inches in diameter. This was placed over the seedling plant with the top covered with a piece of cotton. These cages allowed free circulation of air, thus eliminating all moisture which freely collected on the inside of the globes. These wire cages proved to be the more satisfactory.

The above work at the insectary was checked by making weekly trips to infested orchards in the Berwick district. In this way the progress and habits of the insect were closely followed.

## Eggs

*Where the eggs are laid.* The eggs of the white triangle leaf-roller under natural conditions are deposited in flat masses on the upper surface of apple foliage and on the smooth bark of the larger limbs. This is the only host plant on which eggs have been found. At the insectary, when the globe cages were used, the eggs were laid on the glass and on the leaves of the seedling plant, about evenly divided in this respect. In the wire-screened cages the masses were deposited on the leaves with an occasional one on the bark.

*Number of eggs.* There is a considerable variation in the number of eggs deposited by each female, particularly when one year is compared with another. The average number of eggs deposited in 1927 was only about one-half the number deposited in 1928. In the former year the number deposited by each female varied from 23 to 324 eggs, averaging 187, and in 1928 the variation was 163 to 572, averaging 349 eggs. This fluctuation may occur in nature in any event, but there were a few factors relative to the technique at the insectary which may have contributed at least in part to this difference. Adults were always introduced to the breeding cages very soon after emerging, but in

1927, not having a large number of adults it was seldom possible to add both male and female on the same day, in fact there was frequently a lapse of three days. A little later it became apparent that unless both sexes emerge and are introduced to the cages at the same time, there is a tendency for them not to mate. When the female has not mated, there are invariably fewer eggs deposited and it was found upon examining these unfertilized females that many of the eggs were left in the ovaries at death. In several of the cages in 1927 there was no development of the larvae in the egg masses indicating that they were not fertilized. On the other hand, in 1928, particular care was exercised to have both sexes put in the cages at the same time (immediately upon emerging). As a result, mating occurred in all cages in 1928, and without a single exception there was a high fertility of the eggs.

As a rule the first masses deposited contain the larger number of eggs, followed with the smaller ones at the close of the deposition period. Under natural conditions it seems doubtful if as many masses or as small ones are deposited. No masses could be found outside containing as few eggs as some laid in confinement.

Oviposition of the eggs occurred entirely during the night. As dark approaches the adults are stimulated to activity and it is during the early hours of the evening that oviposition occurs, chiefly between 9 and 11 p.m.

*Duration of the egg laying period.* From field observations during the seasons of 1927 and 1928, egg laying began between June 15 and 20, with the maximum deposition occurring during the last week of June and the first days of July. At the insectary, in 1927, the last egg mass was deposited on July 6, and in 1928 on July 4, but oviposition extended somewhat beyond these dates under natural conditions. The first egg mass is usually deposited on the second or third day after the adult emerges, to be followed, with but few exceptions, by one to three masses each night for a period of about one week.

Practically all the eggs from a fertilized female developed and the majority hatched. In a considerable portion of the masses were a few larvae which appeared fully developed within the egg, but failed for some unknown reason to emerge. This constituted, however, but a small percentage of the total number.

*Duration of the egg stage.* The eggs in a given mass all develop and hatch at nearly the same time, there being rarely more than one hour from the time the first until the last larva escapes from the mass. Hatching always occurs during the early part of the day, usually starting about 7 a.m. and lasting until 10 a.m. In the very largest masses occasionally a few larvae remained until the following morning before escaping from the egg.

In 1927, the incubation period was somewhat longer than in 1928. In the former year this period varied from 11 to 14 days, averaging 12.8 days, and in 1928, 9 to 11 days, averaging 10 days.

The egg-laying records of the individual insects for 1927 and 1928 are given in tables 2 and 3. In the tables, ♀, ♂, indicate female and male; those on the left when they emerged and were placed in the breeding cages; those on the right when they died. The figures under the respective dates indicate the number of eggs deposited.

TABLE 2. *Egg-laying records of C. persicana in 1927.*

| June | | | | | | | | | | | July | | | | | | | | | | Total No. of eggs laid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| ♂ | | ♀ | | 31 | 32<br>24 | 33 | 9 | 10 | | 5 | | 8 | ♀ | ♂ | | | | | | | 152 |
| ♂ | | | ♀ | | | 36 | 24<br>7 | 28 | | 21 | | 25<br>♂8 | | ♀ | | | | | | | 149 |
| | ♂ | | ♀ | | | 43<br>42 | 35 | | 20<br>12 | 20<br>7 | | | ♀ | | ♂ | | | | | | 179 |
| | ♂ | ♀ | | | 24 | 17, 26<br>27, 37 | 46<br>31 | 21 | 32 | 26 | 26 | 11 | ♂ | | ♀ | | | | | | 324 |
| | | ♂ | ♀ | | | 38 | 60<br>20 | 46 | 51<br>29 | | 8 | | ♂ | | | ♀ | | | | | 252 |
| | | ♂ | | ♀ | | 41 | 48<br>19 | 47 | 25 | | | | ♂ | | | | | | | | 180 |
| | | ♂ | | ♀ | | 44 | 16 | 42<br>25 | 24 | 11<br>7 | | | ♂ | | | | | | | | 169 |
| | | | ♂ | | ♀ | | 25 | 6 | 15 | 23<br>21 | | 26<br>5 | | | | | ♀ | ♂ | | | 121 |
| | | | | | | | ♂ | | | | 49<br>61 | 70<br>39 | 11 | ♂ | | | ♀ | | | | 230 |

TABLE 2. (*continued*)

| June | | | | | | | | | | | July | | | | | | | | | | Total No. of eggs laid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| | | | | | | | ♂ | | | 20<br>20 | 47, 21<br>41 | 18 | 23<br>5 | 25<br>16 | ♂ | | | | | | 236 |
| | | | | | ♂ | ♀ | | | | | | | ♂<br>13 | | 10 | | ♀ | | | | 23 |
| | | | | | | | | | ♂ | | 21<br>15 | 46<br>18 | 32<br>12 | 19 | 12<br>11 | ♀ | ♂ | | | | 186 |
| | | | | | | | | | ♂ | ♀ | | | 16<br>18 | 30<br>29 | ♂<br>41 | 40 | 21 | | ♀ | | 195 |
| | | | | | | | | | ♂ | ♀ | | | ♂38<br>40 | 21<br>32 | 16<br>25 | 8<br>11 | 5 | ♀ | | | 196 |
| | | | | | | | | | | ♂ | | | 127 | 50 | 21 | 19 | ♀ | ♂ | | | 217 |

| | | | |
|---|---|---|---|
| Period between emergence of female and egg laying | 2 — 7 days | Average | 3 days |
| Number of eggs laid by each female | 23 — 324 | " | 187.3 |
| Number of eggs in each mass | 5 — 127 | " | 26.7 |
| Number of masses for each female | 2 — 12 | " | 7 |
| Egg-laying period | 3 — 9 days | " | 5.3 days |
| Length of adult life | 7 — 15 days | " | 9.9 days |

| No. pots | June | | | | | | | | | | | July | | | | | | | | | Total number of eggs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| 1 | ♀ | | | 51 | | 73 | | 23 | 43 | | 24<br>48 | 29<br>48 | ♂ | 26 | | ♀ | | | | | 365 |
| 2 | | | ♀ | | | 49 | 69 | 58 | 44 | | 65 | 10<br>42 | | ♂<br>49 | | | ♀ | | | | 386 |
| 3 | | | ♀ | | | | 83 | 66 | | 29<br>61 | 85<br>72 | 61<br>♂ | 62 | 35<br>18 | | | ♀ | | | | 572 |
| 4 | | | ♀ | | | | | 48 | 37 | 38 | ♂<br>20 | 20 | ♀ | | | | | | | | 163 |
| 5 | | | | | | ♀ | | | 39<br>53 | 22<br>43 | 30<br>21 | 24<br>50 | 53 | ♀ | | ♂ | | | | | 335 |
| 6 | | | | | | ♀ | | 63 | 35 | 69 | 30<br>45 | 29 | 22 | ♀ | | | | | | | 293 |
| 7 | | | | | | ♀ | | 61<br>53 | 54 | 64 | 18 | 59<br>28 | 25 | ♀ | | | | | | | 362 |
| 8 | | | | | | ♀ | | | 30 | 36<br>16 | 31 | 42 | 15<br>12 | ♂<br>26 | 12 | | ♀ | | | | 220 |
| 9 | | | | | | ♀ | | 31<br>86 | 51 | 38 | ♂<br>36 | 28<br>36 | 20 | ♀ | | | | | | | 326 |
| 10 | | | | | | ♀ | | | 34 | 45<br>14 | | 31 | 42<br>21 | ♀ | | | | | | | 187 |
| 11 | | | | | | ♀ | | 75 | 73 | | 49<br>18 | 78 | 44 | ♂ | | | | | | ♀ | 337 |
| 12 | | | | | | ♀ | | 65 | 68 | | 71 | 41 | 29<br>38 | ♂<br>13 | ♂ | | | | | | 325 |
| 13 | | | | | | ♀ | | | 41 | 41 | 70<br>32 | 45 | 65<br>37 | ♂<br>31 | 14<br>6 | | | | | ♀ | 382 |
| 14 | | | | | | ♀ | | | 74 | 56 | 53 | 8<br>23<br>50 | 28<br>19 | 11<br>16 | ♂ | | ♀ | | | | 338 |

TABLE 3—(*continued*)

| No. pots | June | | | | | | | | | | | July | | | | | | | | | Total number of eggs laid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| 15 | | | | | | ♂ | | 91<br>21 | | | 89<br>♂75 | 59 | | ♀<br>17 | | | | | | | 352 |
| 16 | | | | | | ♂ | | 58<br>86 | 71 | | 25<br>21 | 57<br>21<br>53 | 34<br>13 | ♂ | | | ♀ | | | | 439 |
| 17 | | | | | | | ♂ | | 44 | 48<br>50 | 16 | 38<br>58 | 35 | 33 | 15<br>♂16 | | | | ♀ | | 353 |
| 18 | | | | | | | ♂ | | 70 | 43 | 53<br>19<br>45 | 9<br>8 | 19<br>66<br>35 | 18<br>8<br>33 | | ♂ | ♀ | | | | 426 |
| 19 | | | | | | | ♂ | | 108 | | 69<br>29 | 75 | 21 | ♂ | | | ♀ | | | | 302 |
| 20 | | | | | | | ♂ | | 128 | 30<br>26 | 60<br>45 | 76 | 40<br>20 | 52 | | 72 | ♂ | | | | 549 |
| 21 | | | | | | | ♂ | | 110 | 23 | 57 | 68 | 52 | 5<br>37 | ♂ | | | | | | 352 |
| 22 | | | | | | | ♂ | | | 60 | 49 | 23<br>26 | 22<br>16 | 20<br>11 | | | ♀ | | | ♂ | 227 |
| 23 | | | | | | | ♂ | | 65 | 52 | 78 | 56<br>55 | 31 | 37 | 16 | ♂8<br>18 | ♀ | | | | 416 |
| 24 | | | | | | | ♂ | | 58 | 35<br>18 | 53<br>60 | 81 | ♂6<br>75 | ♀ | | | | | | | 386 |

♂ denotes male and female, these signs on the left when they emerged, on the right when they died.

| | | | |
|---|---|---|---|
| Period between emergence of female and egg laying | 2 — 5 days | Average | 2.5 days |
| Number of eggs laid by each female | 163 — 572 | " | 349.5 |
| Number of eggs in each mass | 5 — 128 | " | 42.3 |
| Number of masses laid by each female | 5 — 13 | " | 8.3 |

## Larvae

The newly hatched larvae of the white triangle leaf-roller are about one-sixteenth of an inch in length; at first they are very pale, almost white, which colour turns to a pale green. The head is dark brown or blackish. When full grown the larvae are about three-quarters of an inch in length, yellowish-green in colour with two rather pale sub-dorsal longitudinal stripes. The head after the first moult changes to a pale green or amber, which colour is maintained for the remainder of the larval period.

Under natural conditions the larvae begin to make their appearance in the orchard during the last days of June or the first days of July, depending somewhat on the seasons. They continue to emerge over a period of about three weeks. The larvae are to be found feeding upon the trees for the remainder of the season, when they hibernate for the winter. When seeking winter quarters the larvae drop to the ground, fold over one edge of a fallen leaf, securing it with silk along the edge, and thus enclosed pass the winter on the ground. At the time of hibernation they are about one-half the size of the mature larvae. The more advanced larvae begin to desert the trees about the middle of September, but it is the end of October before all have spun up in the leaves on the ground.

The majority, perhaps all, of the larvae, winter in the fifth instar. In confinement a few moulted a fifth time, but the habits of these were such as to lead the writer to conclude that this did not occur in their natural environment. It is possible, however, that under favorable conditions a small percentage may winter in the sixth instar.

Emergence from the hibernating quarters occurs on the first warm days of spring. In 1927, they began to emerge during the first week of May. In 1928, this activity was in evidence during the last week of April. In the latter year, the larvae reached maturity in 28 to 39 days, when pupation occurred. There are two moults in the spring, thus a total of seven larval instars. The rearing records are summarized in tables 4 and 5.

*Habits of the larva.* The larvae of *Cacoecia persicana* Fitch escape from the egg by making a small rent in the delicate shell with their mandibles. As soon as they leave the egg mass they are extremely active and crawl rapidly to the edge of the leaf or down the petiole. In a few moments they release themselves from their secure position and drop suspended by a fine thread spun to some length. This is evidently their method of distribution, and in the event of strong winds at hatching time may be blown for some distance. Many larvae drop to the ground at this time which explains their presence on weeds, etc., previously referred to. It is a definite habit of the larvae to seek shelter where they can hide away. In Nova Scotia, all known orchards with an appreciable infestation of *Cacoecia persicana* Fitch are, also, infested with *Spilonota ocellana* D. & S. The latter insect by tying the leaves and blossoms together provides the necessary shelter for the newly hatched larvae of *Cacoecia persicana* Fitch. After the larvae have developed to about the third instar, they crawl over the tree considerably, and frequently take shelter within the calyx of the apple. The larvae feed by skeletonizing the foliage

TABLE 4. *Length of larval instars and width of head of the white triangle leaf-roller, summer of 1927.*

| Date larva hatched | Head width first instar | Date first moult | Head width second instar | Date second moult | Head width third instar | Date third moult | Head width fourth instar | Date fourth moult | Head width fifth instar | Date fifth moult | Head width sixth instar |
|---|---|---|---|---|---|---|---|---|---|---|---|
| July 9 | .234 | July 16 | .324 | July 21 | .453 | July 30 | .599 | Aug. 10 | .769 | | |
| " 9 | .232 | " 16 | .324 | " 21 | .453 | Aug. 2 | .575 | " 17 | .729 | | |
| " 9 | .234 | " 16 | .323 | " 21 | .469 | " 3 | .582 | " 20 | .679 | | |
| " 9 | .231 | " 16 | .312 | " 21 | .453 | July 30 | .583 | " 14 | .680 | Sept. 10 | .793 |
| " 9 | .232 | " 16 | .308 | " 21 | .437 | " 30 | .583 | " 17 | .680 | " 4 | .712 |
| " 12 | .236 | " 18 | .314 | " 23 | .453 | Aug. 2 | .591 | " 14 | .741 | | |
| " 12 | .235 | " 21 | .324 | " 30 | .437 | " 10 | .550 | " 31 | .648 | | |
| " 12 | .233 | " 20 | .315 | " 26 | .453 | " 6 | .585 | " 20 | .696 | " 4 | .777 |
| " 12 | .234 | " 21 | .316 | " 30 | .437 | " 10 | .534 | " 31 | .617 | | |
| " 12 | .231 | " 21 | .308 | " 30 | .453 | " 6 | .599 | " 31 | .658 | | |
| " 9 | .234 | " 17 | .312 | " 23 | .437 | " 3 | .591 | " 20 | .680 | | |
| " 9 | .231 | " 16 | .309 | " 23 | .453 | " 3 | .599 | " 17 | .712 | " 4 | .782 |
| " 9 | .232 | " 16 | .308 | " 23 | .437 | July 30 | .575 | " 27 | .699 | | |
| " 9 | .234 | " 16 | .323 | " 23 | .469 | Aug. 3 | .582 | " 17 | .680 | | |
| " 9 | .231 | " 16 | .324 | " 23 | .469 | " 3 | .582 | " 17 | .664 | " 10 | .749 |
| " 9 | .234 | " 16 | .323 | " 23 | .469 | " 3 | .599 | " 20 | .696 | | |
| " 12 | .231 | " 18 | .312 | " 26 | .445 | " 6 | .591 | " 20 | .672 | | |
| " 9 | .234 | " 18 | .324 | " 26 | .469 | " 6 | .607 | " 27 | .699 | | |
| " 9 | .234 | " 16 | .324 | " 26 | .437 | " 3 | .567 | " 20 | .648 | | |
| " 9 | .232 | " 16 | .321 | " 23 | .453 | " 3 | .582 | " 17 | .704 | " 9 | .823 |

TABLE 5. *Length of larval instars and width of head of the white triangle leaf-roller, spring of 1928*

| Date first moult in spring | Date second moult | Width of cast head sixth instar | Width of head of mature larva seventh instar | Date pupated | Date adult emerged | Sex | Length of pupal period |
|---|---|---|---|---|---|---|---|
| April 29 | May 18 | .946 | 1.235 | June 6 | June 25 | ♀ | 19 days |
| May 12 | " 30 | .741 | 1.070 | " 11 | " 27 | ♂♀ | 16 " |
| " 3 | " 23 | .863 | 1.152 | " 6 | " 25 | ♀ | 19 " |
| " 3 | " 18 | .905 | 1.152 | " 3 | " 24 | ♂♂ | 21 " |
| " 3 | " 18 | .864 | 1.111 | " 3 | " 24 | ♂ | 21 " |
| April 27 | " 9 | .729 | 1.029 | May 30 | " 20 | ♂ | 21 " |
| — | " 9 | .823 | 1.194 | June 8 | " 26 | ♀♀ | 18 " |
| — | " 18 | .823 | 1.070 | " 3 | " 24 | ♂♀ | 21 " |
| — | " 18 | .844 | 1.194 | " 14 | July 1 | ♀ | 17 " |
| — | " 9 | .802 | 1.132 | " 8 | June 27 | ♀♀ | 19 " |
| — | " 12 | — | 1.194 | " 11 | " 27 | ♀ | 21 " |
| May 9 | " 23 | .770 | 1.111 | " 6 | " 25 | ♂♂ | 19 " |
| " 2 | " 23 | .728 | 1.029 | " 6 | " 26 | ♂♂ | 20 " |
| " 3 | " 23 | .782 | 1.111 | " 8 | " 27 | ♂♂ | 19 " |
| " 9 | " 23 | .712 | 1.122 | " 11 | " 29 | ♀♀ | 18 " |
| " 2 | " 23 | .749 | 1.152 | " 6 | " 26 | ♀♀ | 20 " |
| " 5 | " 23 | .720 | 1.111 | " 11 | " 28 | ♂♂ | 17 " |
| " 4 | " 23 | .864 | 1.173 | " 8 | " 27 | ♀♀ | 19 " |
| " 3 | " 23 | .823 | 1.194 | " 6 | " 26 | ♀♀ | 20 " |
| " 4 | " 23 | .823 | 1.194 | " 8 | " 27 | ♀♀ | 19 " |
| " 2 | " 19 | .782 | 1.070 | " 3 | " 24 | ♂ | 21 " |

which makes up these shelters or is in contact with them, the amount consumed, however, being rather small. There is no accumulation of grass at any time about the places they frequent. As the season advances and the larvae come into contact with the fruit, leaves are drawn together in close contact, resulting invariably in scarred fruit at picking time. Due to winds, rain, etc., many larvae are dislodged from the trees prematurely. During the severe gale of August 26, 1927, it was estimated that 25 to 40 per cent of the larvae were removed from the trees. These larvae feed upon the vegetation beneath the trees and also skeletonize the apple leaves which have recently dropped.

When preparing to hibernate, the larvae fold over one edge of a freshly fallen leaf securing it with silk along the edge, and thus enclosed pass the winter on the ground.

In the spring, the larvae skeletonize a portion of the leaf within which they have hibernated, and moult before emerging to feed on the surrounding vegetation. This is borne out by the fact that the moulted head capsule is usually found within the hibernating quarters. They first feed on the grass, weeds, etc., and move quite freely from plant to plant. Soon after emerging they begin to ascend the trees. This, in 1928, began on May 2, the larvae continuing to ascend in small numbers well up to the time of pupation. In all probability a small number of larvae mature without ascending the trees, but this depends largely upon the abundance and the species of plants growing in the orchard. If an obstruction is placed on the trunk, such as a band of tanglefoot, many drop back and feed on the plants beneath the tree.

Those that ascend the trees spin some silk around the expanding buds and under this thin protection feed upon the tender leaves. In only a few

## Explanation of Symbols Applied to Head

$A^1$, $A^2$, $A^3$, $A^a$—setae and puncture of anterior group of epicranium.
$Adf^1$, $Adf^2$, $Adf^a$—adfrontal setae and puncture of epicranium.
ADFR—adfrontal ridge of larval head.
ADFS—adfrontal suture of larval head.
$E^1$, $E^2$—epistomal setae.
$F^1$, $F^a$—frontal setae and puncture of epicranium
FR—frons of epicranium.
$G^1$, $G^a$—genal setae and puncture of epicranium.
$L^1$, $L^a$—seta and puncture of lateral group of epicranium.
LR—longitudinal ridge of epicranium.
$O^1$, $O^2$ $O^3$—setae of ocellar group of epicranium.
$P^1$, $P^2$, $P^a$, $P^b$—setae and punctures of posterior group of epicranium.
$SO^1$, $SO^2$, $SO^3$, $SO^a$—setae and puncture of subocellar group of epicranium.
X—ultra posterior setae and puncture of epicranium.
$M^1$, $M^2$, $M^3$—median group of setae of labrum.
$La^1$, $La^2$, $La^3$—lateral group of setae of labrum.

## Explanation of Symbols Applied to Pupa

a—antenna
a, 1 to 10—abdominal segments
ao—anal opening
cl—clypeus
cr—cremaster
f—front
$f^1$—femur of prothoracic leg
ge—glazed eye-piece
go—genital opening
lb—labrum
$l^1$—prothoracic leg
$l^2$—mesothoracic leg
$l^3$—metathoracic leg
lp—labial palpi
md—mandibles
mp—maxillary palpus
ms—mesothorax
mt—metathorax
mx—maxilla
p—prothorax
se—sculptured eye-piece
v-vertex
$w^1$—mesothorax wing

## Explanation of Symbols Applied to Genitalia

ae—aedoeagus
Jx—juxta
Cn—cornuti
Gn—gnathos
Hp—harpe
U—uncus
Vm—vinculum
Tg—tegumen
Ts—transtilla

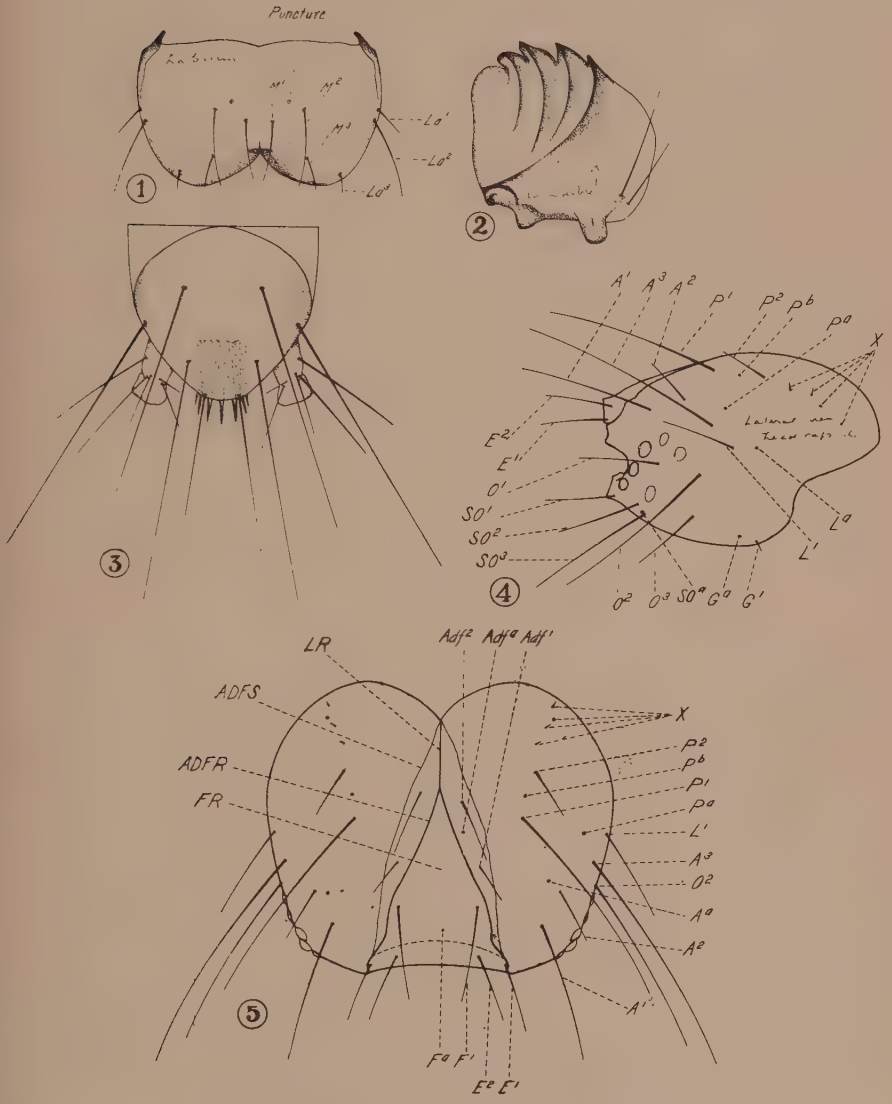
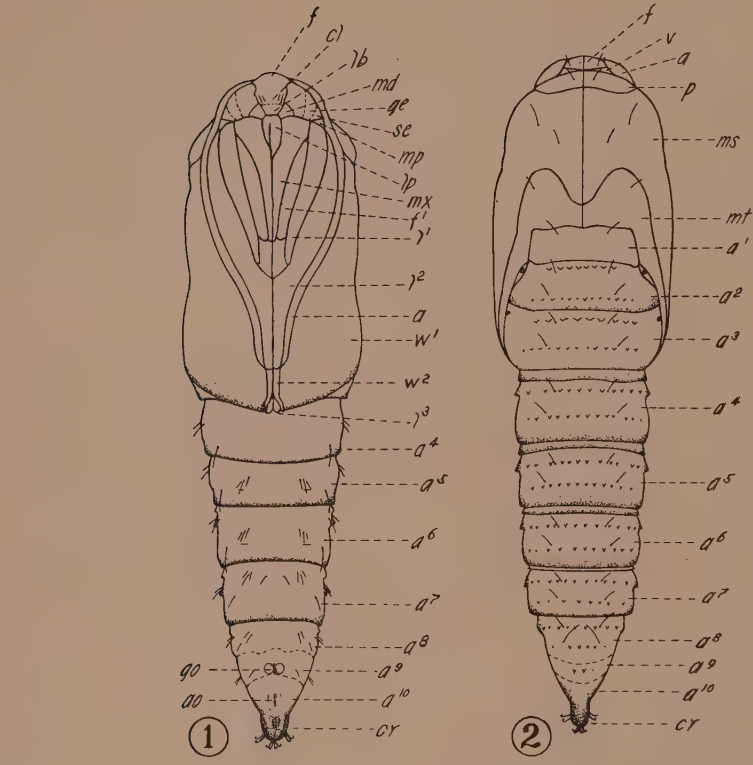



Plate 1. *Cacoecia persicana* Fitch; larva.

1. Labrum.
2. Mandible.
3. Caudal segment of larva.
4. Lateral view of head capsule.
5. Dorsal view of head capsule.



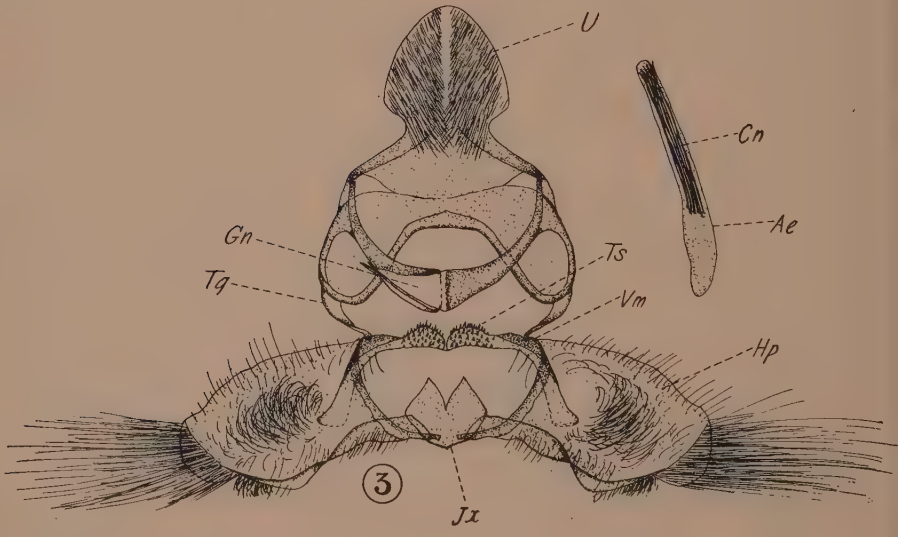




Plate 2.

1. Pupa, male, ventral view.
2. Pupa, male, dorsal view.
3. Male genitalia.

instances have they been observed to bore into the buds. The larvae feed singly in the spring, and after the leaves unfold move frequently from one leaf to another, the foliage being drawn together in the familiar "leaf-roller" manner. When disturbed, the larvae wriggle violently, often leaping in the air, and drop to the ground without the aid of any silk. This apparently is their method of escape from enemies.

When mature, the larvae crawl down the trunk and either pupate under the rough bark or descend to the ground to pupate in the fallen leaves near the base of the tree.

### Pupa

The pupa, which is less than one-half of an inch in length, is greenish-brown when first formed, but later turns to a chestnut brown with the wing covers still retaining a tinge of green. The pupa is found under the loose bark on the trunks in the orchard, where a small pupal cell is formed. The bark on the trunks in the orchard, where a small pupal cell is formed. The cell is usually lined thinly with silk. A small percentage of pupae are found near the base of the tree where the larvae have descended. These sew over one edge of a fallen leaf to form a protective pupal cell.

In the average season, a few pupae may be found during the last days of May, but the most active period for their transformation begins June 1, lasting for the next two or three weeks. The average duration of the pupal stage in 1927 was approximately fifteen days and, in 1928, nineteen days.

### Adult

The adult measures, with the wings spread, about three-quarters of an inch. The basal half of each fore wing is orange ochre, the outer half dark brownish; extending across the outer margin is a lighter band, light ochre in colour, mixed with some yellow and white. On the upper or costal margin is a prominent white triangle, which suggested the common name, "The White Triangle Leaf-roller," for this species. The hind wings are smoky without characteristic markings.

The average life of the adults, both in 1927 and 1928, was 9 to 10 days, representing 80 adults. In the former year the sexes were about equal in number, but in 1928 the females exceeded the males considerably.

*Period of emergence.* The first adult emerged at Annapolis Royal in 1927 on June 17 and in 1928 on June 15. As these moths were obtained from pupae collected in the orchard, these dates should be representative of field emergence. The adults emerge over a period of from three to four weeks, with the maximum occurring in most seasons the last week in June.

*Habits in the field.* The adults are not active during the day and unless present in considerable numbers are not readily observed. They may be found among the grass, on the foliage of the trees, and frequently at rest upon the trunk. When disturbed they fly away quickly in an irregular course, and are quite elusive, it being difficult to follow them in their flight. At dusk they become more active, especially during the early part of the evening. They respond very little to light and are apparently only feebly attracted thereto.

*Habits in the insectary.* In the insectary, the adults all emerged during the night. Mating has not been observed during the day, but occurred at night, usually during the early evening from 9 to 11 p.m. In most instances the females mated on the following night after emerging. If mating did not occur by the second night the female usually remained unfertilized. Mating was observed in a number of cages beginning at 9 p.m., adults remaining in copula until 11 p.m. The following morning they were in different parts of the cage. An attempt was made to mate a male with more than one female, but this always gave negative results. Oviposition begins two to five days after the adults emerge, usually on the third day. The eggs were all laid during the early part of the night. The following note was made in 1928 relative to oviposition: "June 29, 9:15 p.m. The female has her wings folded as if at rest and when in the act of ovipositing there is a slight swaying of the caudal extremity—a trembling motion. The abdomen at this time cannot be observed as it is hidden by the folded wings which are held in close contact to the leaf. She backs up as each row of eggs is completed in the mass in order to start a new one. After the last egg is deposited she flies at once to another part of the cage and remains at rest. It took twenty-four minutes to deposit a mass of fifty-three eggs."

## Nature and Extent of Injury

Injury to the fruit begins soon after the larvae hatch. Wherever the webbed foliage within which the larvae are sheltered comes into contact with the fruit, injury invariably follows. To a large extent fruit feeding appears to be a matter of chance, especially during the early part of the larval period. After the larvae have reached about the third instar they scatter more widely over the trees, for up to this time there may be eight to ten larvae congregated in one shelter. They now locate more readily about the fruit which they seem to prefer.

The injury to the fruit consists of shallow surface feeding, frequently forming irregular paths on the surface of the apple. Fruit thus scarred during the early part of the season forms a protective covering over the injured surface sufficient to prevent decay. This is not so readily formed later in the season, resulting frequently in decay soon after picking. The larvae which find their way into the calyx of the apple cause very little injury within, but they frequently reach out to feed, producing small circular or irregular disconnected holes near the calyx. Frequently around the calyx of apples thus injured, there is a whitish deposit which is often quite conspicuous and unsightly. To a less degree this may also be noticed upon the fruit injured from the side. As to the cause for this the only explanation which the author can offer is that the juices which issue from the eaten surface upon drying leave this incrusted, creamy, deposit.

During the picking operations larvae are liable to gain access to the barrels of fruit thus causing further damage. In 1927, fifty larvae were placed in a barrel of Gravenstein apples free of any insect injury. When examined a few weeks later 12.7 per cent of the fruit was found to be injured.

Plate 3.

1. Adult moths, male and female.
2. Apple showing the incrusted white deposit and injury near calyx.
3. Egg masses on leaf.
4. Type of breeding cage used in insectary.
5. Couch grass blade showing method of feeding after hibernation before larvae ascend trees.

## Ecological Factors

Whether the white triangle leaf-roller is to be found in destruc numbers depends largely upon the environment. There is woven into life history and habits a definite association with other insects. From writer's experience *Spilonota ocellana* D. & S. is the most important associa in this respect, but any insect with habits of a similar nature could proba be associated in like manner.

Reference has been made elsewhere to the fact that the larvae *Cacoecia persicana* Fitch feed more or less concealed during the whole la period, with this habit particularly in evidence just after hatching. At time the larvae appear unable to spin or provide shelter. As a result shelter is not readily available, the larvae continue to spin down from to leaf until at least the larger number drop to the ground. But the lar can readily mature, at least to a considerable degree, upon the vegeta growing beneath the trees, if such be present. It would appear that in absence of other insect associations, the white triangle leaf-roller, altho found in more restricted habitats, is not capable of increasing in numb sufficiently to become an important orchard pest. The general outbreaks the Annapolis Valley of *Spilonota ocellana* D. & S. in recent years has p vided an environment suitable for an increase of *Cacoecia persicana* Fitch, apparently is largely responsible for the prominence of the latter insect. the other hand as *Spilonota ocellana* D. & S. becomes more under con it is the author's opinion that there will be a more or less correspond reduction of *Cacoecia persicana* Fitch.

## Economic Importance

As a pest of the apple, the white triangle leaf-roller has been un observation only since 1926, and it is, therefore, rather premature to pre just how serious an orchard pest it may become. As a leaf feeder it probably always remain as a minor insect, but must be classed as one o large group of destructive species, the larvae of which feed upon and r the surface of the fruit. In 1927, considerable loss was recorded in m orchards, principally in the Lakeville district. There was somewhat injury in 1928.

The following records were collected in 1927 from orchards un close observation. These orchards were sprayed or dusted in all ca very copiously, but were not conducted as control experiments for particular insect.

The high percentage of scarred fruit in the Lakeville orchard is evide of the fact that this insect is capable of causing very definite financial to fruit growers. The amount of injury in the other orchards represe what may be found in many others in the same district.

As previously mentioned, *Cacoecia persicana* Fitch is closely associa with *Spilonota ocellana* D. & S. In orchards comparatively free of the la insect and where clean cultivation is practised, the white triangle le roller will apparently remain obscure. On the other hand, as long as

TABLE 6. *Percentage of apples injured by larvae of C. persicana Fitch.*

| Locality | Variety | Treatment | No. apples counted | Percentage of fruit injured |
|---|---|---|---|---|
| Berwick | Gravenstein | 4 sprays | 1800 | 9.6 |
| " | " | " | 700 | .8 |
| " | " | " | 2300 | 1.7 |
| " | " | " | 1000 | 14.7 |
| " | Kings | " | 1000 | 1.7 |
| " | " | " | 800 | 1.6 |
| " | " | " | 700 | .5 |
| " | Spys | " | 2000 | .6 |
| " | " | " | 1500 | .3 |
| " | " | " | 1500 | .3 |
| " | Golden Russet | " | 4500 | .35 |
| " | " | " | 3500 | .05 |
| " | " | " | 4000 | .15 |
| Starr's Point | Kings | " | 2000 | 1.2 |
| " | " | " | 2000 | 1.1 |
| " | " | " | 2000 | 1.35 |
| " | " | " | 2000 | 1.4 |
| " | " | " | 2000 | 1.3 |
| " | " | " | 2000 | 2.8 |
| " | Ribston | " | 26000 average of 13 plots | 1.04 |
| Lakeville | Wolf River | 1 spray, 6 dusts | 5100 | 30.2 |
| " | Ribston | 1 " 6 " | 3000 | 44.2 |

present epidemic of eye-spotted budmoth exists and grass and weeds are allowed to grow beneath the trees, there is danger of this insect becoming a major orchard pest in the Annapolis Valley.

## PARASITES

This species, like many of our insect pests, has its natural enemies which assist in holding it in check. Several species of parasites have been recovered, and include at least four species of ichneumon flies, one braconid and two dipterous species. The parasites, however, were not sufficiently numerous to cause any great reduction in their host.

## TECHNICAL DESCRIPTIONS OF THE STAGES

*Egg.* The individual egg is flattened, scale like, ovate in outline, averaging .946 mm. by .679 mm. The entire surface is covered with a network of very fine ridges, forming small cells. When laid the colour is pale yellow, semi-translucent, which changes slowly to a dull orange or occasionally to a wine colour, at the same time becoming more opaque. From two to four days previous to hatching the eye spots become visible, and a little later the brownish head and mandibles are distinguishable through the egg shell. At the same time the egg loses its former colour and is now quite dark. Each larva can be readily distinguished curled up in the form of a circle within the egg.

## LARVA

*First instar.* Width of head .231 mm. to .234 mm.; total length of body 1.52 mm. to 1.64 mm. Head brownish-black, ocellar area same colour,

inconspicuous; clypeus pale; mandibles rusty, darkened at teeth; antennae and setae pale. Prothoracic shield large, wider than head, same colour as body. Body cylindrical, pale yellow, tubercles and anal plate of the same body colour, inconspicuous, setae pale, rather long, standing out stiffly from body; spiracles small, circular; thoracic feet and pro legs same colour as venter; anal fork distinguishable.

*Second instar.* Width of head .307 mm. to .332 mm.; total length of body 2.67 mm. to 3.11 mm. Head pale amber; ocelli blackish. Body yellowish white, digestive tract along dorsum often a reddish brown; venter slightly paler than dorsum. In other respects as in previous instar.

*Third instar.* Width of head .422 mm. to .469 mm., total length of body 5.62 mm. to 6.91 mm. Except that the prothoracic shield is of an amber colour and the abdomen a yellowish-green with the venter slightly paler than the dorsum, the general appearance of the larva in this instar is much the same as those preceding.

*Fourth instar.* Width of head .534 mm. to .607 mm.; total length of body 7 to 8 mm. There is on the body a medio-dorsal pale green stripe; sub-dorsal stripes pale; supra-lateral stripes same color as dorsal stripe or slightly paler. These stripes are rather irregular in outline, and frequently are not very clearly defined. In other repects as in previous instar.

*Fifth instar.* Width of head .615 mm. to .769 mm.; total length of body 8 to 9.5 mm. The colour of head and other body markings show no marked difference from the previous instar, except that the green and pale stripes are somewhat more consistent and more clearly defined.

*Sixth instar.* Width of head .712 mm. to .946 mm.; total length of body 9 to 11 mm. Head a pale amber, a shaded area on epicranium with base resting on hind margins; a small dark brown area on lateral margins adjacent to prothorax; frons pale green; clypeus same colour as frons; labrum amber but slightly darker than head; mandibles rusty, decidedly darker at teeth; ocellar area dark brown or blackish; setae rather long, golden in colour. Prothoracic shield wider than head averaging 1.029 mm., almost straight in front, rounded behind, same colour as head or occasionally a nile green. Body pale green, venter paler than dorsum; stripes always present in varying degrees; tubercles raised, shining,rugose; setae golden, straight, moderate length; anal plate same colour as dorsum or slightly paler; spiracles circular with a brownish border; anal fork 6 or 7 pointed; feet and prolegs concolorous with venter.

*Seventh instar.* Width of head 1.029 mm. to 1.235 mm. General colour pale green or amber; front and area adjacent a blue green; caudad of a line from ocelli to upper angle of frons a tinge of orange; ocellar area black; antennae composed of 4 joints, first cone shaped and whitish; second about same length as first, cylindrical, brownish; third cylindrical, much smaller and same colour as second; fourth very small, coming to a sharp point, rusty; clypeus same colour as frons slightly darker on margins; labrum and mandibles rusty, latter dark brown at teeth; setae moderate length, golden; prothoracic

Plate 4.

1. Leaf with one edge sewed enclosing hibernating larva.
2. Leaf opened to show larva in hibernating quarter.
3. Apples injured from the side.

shield wider than head, 1.276 mm. to 1.40 mm., pale green, occasionally oli green, frequently darker on caudal margins.

Head capsule wider than long, greatest width in line with upper ang of frons; incision of dorsal hind margin about one-seventh the width head; frons (FR) longer than broad, reaching beyond middle of head; lon itudinal ridge (LR) a little longer than one-third length of frons; adfron suture (ADFS) reaching to dorsal hind margins; adfrontal ridges (ADFR sensuate; ocelli six, III, IV, and V close together in nearly a straight lin the margins of these three lenses are heavier and darker than the othe VI outline faint, well separated from IV and V; epistoma with the norm setae ($E^1$, $E^2$); frontal puncture ($F^a$) very faint; distance from frontal se ($F^1$) to first adfrontal seta ($Adf^1$) less than between $Adf^1$ and $Adf^2$. Epicra ium with the normal number of primary setae and punctures, and three sma ultraposterior setae and one puncture. Anterior setae ($A^1$, $A^2$, $A^3$,) formi a very obtuse angle and almost in line with $L^1$; the distance between $A^1$ a $A^2$, $A^2$ and $A^3$, $A^3$ and $L^1$ about equal. Posterior setae ($p^1$) only slight behind middle of head; posterior puncture ($p^a$) at middle of head; $L^1$, $p^a$, p and adfrontal setae ($Adf^2$) in a line; ocellar setae ($0^1$, $0^2$, $0^3$) well separate $0^1$ and $0^2$ equal distance from ocelli I; $0^3$ almost directly ventrad of $0^2$, remo and postero-ventrad of ocelli VI; ocellar puncture $0^a$ in line with $0^2$ and and approximate to $0^3$, subocellar setae ($SO^1$, $SO^2$, $SO^3$) in almost a straig line; $SO^2$ nearer to $SO^3$ than $SO^1$; genal setae ($G^1$) and puncture (G both present, puncture anterior and slightly dorsal of seta.

Body cylindrical, widest in region of abdominal segments 3 and tapering gradually toward both extremities; general colour pale green, ventr surface paler than dorsal; a medio-dorsal green stripe, sub-dorsal stripe pale; supra-lateral stripes same colour as dorsal or slightly lighter; stripes a fainter on thorax and caudal extremity; occasionally two orange coloure glands on abdominal segment 5; tubercles raised, shiny, slightly rugose, sam colour as sub-dorsal stripe of which it forms a part; setae golden, modera length; spiracles pale brown, small, circular; spiracle on pro-thorax and th on abdominal segment 8 larger than others, spiracle 8 higher on dorsum tha spiracles 1 to 7; anal plate concolorous with dorsum, with small dark mottlings; prolegs and feet concolorous with venter, tarsus on the latte brown; crochets in a complete circle on planta, uniserial apparently of thre lengths, but not uniformly triordinal; anal fork 7 pointed, two lateral fork short.

Length of larva 10 mm. to 11 mm. when first moulted.

Length of larva 15 mm. to 20 mm. when mature.

### Pupa

When first formed, head and thorax and appendages green wit a tinge of brown; eye spots dull and blackish, abdomen orange-brown, dorsa surface darker than ventral, caudal margin of 1 to 7 abdominal segment and margin of wings darker; cremaster only slightly darker than abdome Later the entire pupa turns darker varying from light to dark brown wit the wings usually retaining a tinge of green; cremaster is now dark brow or blackish.

Fronto-clypeal suture not distinct; two pairs of clypeal setae, outer pair slightly longer than inner, suture between labrum and clypeus faint; prothoracic legs extending one-half way to tip of wings, their femora exposed which reach to end of maxillae; mesothoracic legs not reaching to tip of wings; metathoracic legs and tips of wings reaching slightly beyond cephalic edge of fourth abdominal segment; antennae same length as mesothoracic legs; proleg scars visible on abdominal segments 5 and 6; two transverse rows of spines on dorsum of abdominal segments 2 to 8; cephalic rows on segments 2 and 3 somewhat flattened; spines on caudal row of segment 8 few in number; segment 9 with only 2 to 3 spines; cremaster prominent, roughened, with 4 hooks at extremity curved ventrad, two hooks on lateral margins curved at tips; female genital opening a dark slit without elevations; male genital opening slit-like with elevations on either side; anal opening slit-like in both sexes, no setae on anal rise. In the male there is independent movement between segments 7 and 8, in the female there is apparently no movement between these two segments.

Length of pupa 8.81 mm. to 10.31 mm.; width 2.24 mm. to 2.66 mm. As a rule the females are slightly larger and stouter than the males.

### Adult (Original description)

"The moth with the fore wings rusty yellow varied with black, their basal third much paler tawny yellow; a large triangular white spot on the middle of the outer margin; a transverse white streak forward of the middle of the hind edge, which is divided by the veins crossing it into about four spots, and is bordered on its anterior side by a curved black band width 0.65."

The Nova Scotia forms vary from 17 mm. to 22 mm. with wings spread. There is very little difference in size of males and females. The male genetalia is as figured on Plate 2.

### LITERATURE CITED

1. Fitch, Asa. Third report on the noxious, beneficial, insects, of the State of New York. New York, Agr. Rept. 1856.
2. Winn, Albert F. A preliminary list of the insects of the province of Quebec, p. 91, 1912.
3. Forbes, William T. M. The lepidoptera of New York and neighboring States, Memoir 68. Cornell Univ. Exp. Sta. p. 497, 1923.
4. Leonard, M. D. A list of the insects of New York. Memoir 101, Cornell Univ. Agric. Exp. Sta., p. 569, 1926.
5. Perrin and Russell. Catalogue of butterflies and moths collected in the neighborhood of Halifax and Digby, Nova Scotia. Trans. of the Nova Scotia Institute of Science. XII: 3, pp. 258-290. 1912.
6. Fernald, C H. A synonymical catalogue of the described Tortricidae of North America north of Mexico. Trans. of the American Ent. Society, X, p. 14. 1882-83.
7. Gilliatt, F. C. A preliminary report on some of the budmoths and leaf-rollers of Nova Scotia. Ent. Soc. Ont. Report, p. 36, 1927.
8. ———————— A key to certain tortricid larvae occurring in Nova Scotia with notes on their habits and life histories. *Scientific Agriculture*, X: 2, Oct. 1929.

# FIELD STUDIES OF TAKE-ALL IN SASKATCHEWAN *

R. C. Russell †
*Dominion Laboratory of Plant Pathology, Saskatoon, Sask.*
[Received for publication March 21, 1930].

Take-all, caused by *Ophiobolus graminis* Sacc., is one of the soil-bor diseases of cereals which are commonly called root-rots or foot-rots. Seve diseases of this kind are prevalent in Saskatchewan and each of them is caus by a different organism or combination of organisms. Each disease has own peculiar characteristics and the facts relating to any one of them can be applied in their entirety to the others. The reactions of the causal orga isms to physical conditions are not identical, they do not all yield to the sa measures of control, and they differ in other respects. Hence, it must kept in mind throughout this paper that what is stated applies particula to take-all.

Take-all has a longer historical record than any other root-rot cereals. The first references to the disease under this name came fr Australia about 1870 (*21*). McAlpine (*20*) was the first to recogni *O. graminis* as the cause of take-all in Australia. Summers (*35*) a McAlpine (*21*) both give some very interesting information about the ea history of the disease. Prillieux and Delacroix in France associated piét and *O. graminis* in scientfic literature as early as 1890 (*25*). These ea articles state that take-all and pietin had been troublesome in Australia a France, respectively, for at least fifty years previous to the time when th wrote. Subsequently, reports of take-all have come from practically eve important wheat growing region in the world (*1, 2, 6, 8, 10, 13, 14, 17, 1 22, 23, 24, 26, 32, 38, 39, 40*).

This disease first became a live problem in Canada in 1923, althou the Dominion Botanist expressed his suspicion, since confirmed, that it w present in Saskatchewan as early as 1916 (*15*). Probably the fact that t characteristic fruiting bodies of the causal organism are seldom found this region explains why this fungus was not recognized much sooner, for appears to be indigenous to Western Canada. Late in the summer of 192 W. P. Fraser, then officer-in-charge of the Dominion Laboratory of Pla Pathology at Saskatoon, inspected a field of wheat near Annaheim, Saska chewan, which was clearly infested with take-all (*10*). Stubble gathered the in the autumn bore numerous perithecia, and the fungus was isolated in pu culture from this material. Since then the problem has been investigate annually in the field and laboratory (see sections relating to take-all in t annual reports of the Dominion Botanist for the years 1923-29).

*O. graminis* is now known to be widely distributed in the three prair provinces (*11, 33*) and it has also been discovered in Quebec, Nova Scot and Prince Edward Island. In this article we will not deal with the laborato and greenhouse experiments which we have conducted but confine the di cussion to our field observations and experiments relating to control.

*Contribution from the Division of Botany, Experimental Farms Branch, Department Agriculture, Ottawa, Ont., Canada.
†Plant Pathologist.

## Description of the Disease

A number of wild and cultivated grasses are more or less affected by this disease. The injury which it causes to wheat, however, is of far greater economic importance than is the injury which it causes to its other hosts, so we will confine the discussion mainly to take-all of wheat.

The disease has fairly definite symptoms, but these vary somewhat with the stage at which the plant is stricken and with the amount of moisture present. On comparatively new land the diseased plants usually appear in definite patches but on older land the infestation tends to become more scattered. Under our conditions the plants may die at any period from the late seedling stage to maturity, but in the field the disease is usually most evident during the late growing period. The affected plants become unthrifty, lose colour and die. According to the stage at which they are killed, they may never head out, they may produce empty heads, or they may yield grain which is more or less shrunken. An examination of the basal parts usually shows that the roots and sub-crown internodes are somewhat decayed and blackened. If conditions have been fairly moist, the crowns may be noticeably affected and a brownish-black mycelial growth, forming a thin crust over the culm, may be found between the inner sheath and the culm at the base of the plant (see Figure 1.). Under moist conditions the crown roots are often rotted off close to the base of the culm and in such cases the diseased plants can be pulled up very easily. Sometimes minute fruiting bodies, perithecia, can be found embedded in the sheath of the host. The dark mycelium and the perithecia belong to the fungus, *Ophiobolus graminis* Sacc. In Saskatchewan, conditions at mid-summer are frequently so dry that the dark fungous growths inside the sheaths are poorly developed and perithecia are not commonly found but the primary roots and sub-crown internodes are usually noticeably discoloured and exhibit the typical mycelium of *O. graminis*. Other fungi, including *Wojnowicia graminis* (McAlp) Sacc. and D. Sac., *Helminthosporium sativum* P.K. & B. and *Fusarium spp.* are often present as well as *O. graminis* on plants exhibiting the symptoms of take-all. Nevertheless, from studying the action of pure cultures of these organisms upon the wheat plant under controlled conditions, and from continued critical field observations, we believe that *O. graminis* is the principal cause of take-all.

It is sometimes difficult for the average person to identify take-all with certainty. About the best characteristic by which one can distinguish it from all other root-rots known in Saskatchewan, is the presence of typical, dark-brown, mycelial growths found on the roots, the sub-crown internodes, and the lower parts of the culms and sheaths of the host. Figure 2a shows a few strands of loose mycelium on the inner surface of a wheat sheath. Mycelium similar in appearance is found on the surface of the roots (see Figure 2b). In such cases as these, where the mycelial growth is loose, the hyphal branches generally grow out at an acute angle from the main strand. Almost invariably the branch arises at a point near the forward end of the cell from which it grows and the first septum in the branch is situated close to the junction. Another characteristic of the mycelium of *O. graminis* is

Figure 1. Crown and culm-base of a wheat plant heavily infected with *O. graminis*. Fragments of the typical dark mycelial crust appear on the culm and inner surface of the sheath.

a tendency for the hyphae to develop in groups of two or more individual strands running parallel (see Figure 2c). In such cases the branches given off sometimes remain close to the parent hypha thus increasing the number of strands in the group. The mycelial growth forming the thin dark crust mentioned previously, is composed mainly of short irregular cells which develop in such close contact with each other that they form a solid plate (see Figure 2d).

## Distribution

Take-all has been found in every part of Saskatchewan except the South-western area. As a rule, however, only traces or light infections appear in open plains country. The districts in which it is most prevalent are semi-wooded (see Figure 3). The accompanying map shows the districts in which take-all has been found but continued search is likely to reveal its presence elsewhere (see Figure 4). The Humboldt and Melfort districts have been surveyed for take-all more thoroughly than most other parts of the province and that explains to some extent why that area is so thickly dotted on our

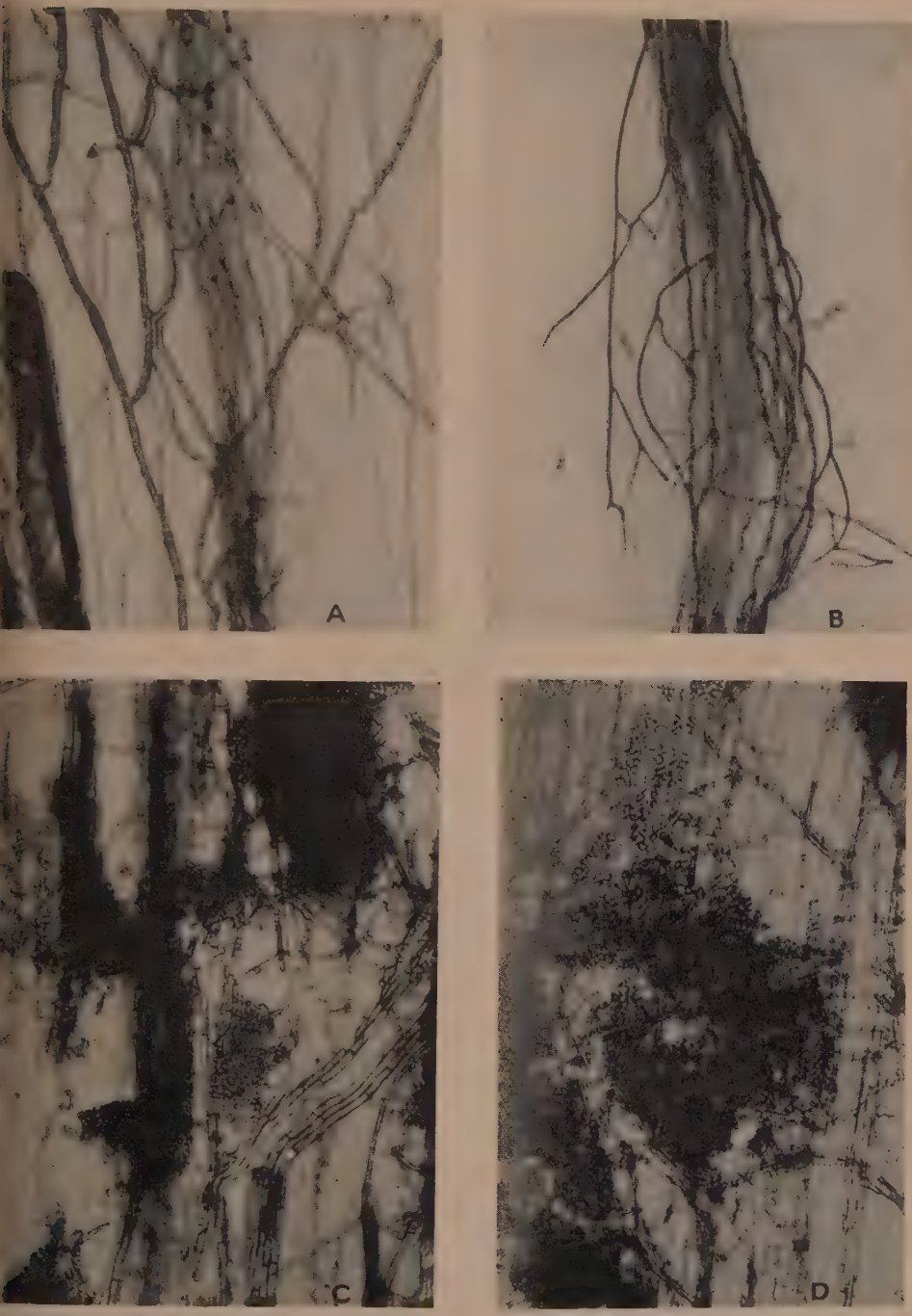



Figure 2. Mycelial growths of *O. graminis.* (a) scattered hyphae growing upwards on the inner surface of a wheat leaf-sheath, (b) scattered hyphae following a wheat root downward, (c) parallel strands of hyphae and small mycelial plates and (d) a small mycelial plate.

map. Take-all is very often present in wheat which is growing on comparatively new land or on land which has had brome or western rye-grass on it for some years and which has recently been re-broken. Wheat crops on older fields which have raised oats occasionally and which have been summer-fallowed regularly are seldom appreciably injured by take-all. Therefore, the distribution within any small district depends largely upon the crops which the land has produced.

## Economic Importance

As nearly as we can estimate it, the amount of injury which take-all causes to wheat crops in Saskatchewan varies from next to nil up to about forty per cent of the whole crop. In 1928 we gathered 100 healthy-looking plants and also 100 representative diseased plants (see Figure 5) from each of ten different fields and threshed and weighed the yields from these. The reduction in weight due to the disease was found to vary from 80 to 92 per cent. At the same time there was on the average a reduction in quality of about one grade. As the percentage of plants (by estimate) which was diseased varied in the different fields from 2 to 20 per cent, the computed loss varied from 1.6 per cent to 18.3 per cent in these particular fields (see table 1).

Table 1. *Comparison in yield and grade of healthy and diseased wheat as determined from 100-plant samples collected at various points in Northeastern Saskatchewan in 1928.*

| Sample Number | Healthy | | Diseased | | % reduction | | % of crop diseased | Computed loss in % |
|---|---|---|---|---|---|---|---|---|
| | Grams | Grade | Grams | Grade | Weight | Value | | |
| 1 | 222 | 2 | 32 | 4 | 85.5 | 13.5 | 12 | 10.26 |
| 2 | 152 | 4 | 28 | 5 | 81.5 | 9.5 | 2 | 1.63 |
| 3 | 277 | 4 | 34 | 4 | 87.5 | 0 | 3 | 2.62 |
| 4 | 83 | 6 | 16 | Feed | 80.5 | 10.5 | 5 | 4.02 |
| 5 | 192 | 5 | 16 | 6 | 91.5 | 5.5 | 20 | 18.30 |
| 6 | 120 | 5 | 15 | Feed | 87.5 | 15.5 | 10 | 8.75 |
| 7 | 185 | 3 | 15 | Feed | 92.0 | 30.0 | 8 | 7.31 |
| 8 | 155 | Feed | 18.5 | 6 | 88.0 | −10.5 | 3 | 2.64 |
| 9 | 122 | 6 | 19 | 6 | 84.5 | 0 | 8 | 6.76 |
| 10 | 95 | 5 | 9 | 6 | 90.5 | 5.5 | 5 | 4.52 |

Note:—Grading was done by Mr. Rose of the Robin Hood Mills, Saskatoon. The computation of loss takes into consideration only the reduction in yield, as the amount of poor quality wheat in the total crop would not likely be enough to affect the grade except in fields 1, 5 and 6.

## Fluctuations in Severity Correlated with Summer Rainfall

Take-all has varied considerably in severity during the period of our investigations. This appears to be a common characteristic of the malady the world over, judging by the literature on the subject (*10, 17, 31, 34*). There appears to be a marked positive correlation between the amount of rainfall occurring between the first of June and the middle of August and the severity of the disease during the same season. This fact has become apparent to us during our annual field surveys of Northeastern Saskatchewan. Figure 6 shows in the form of a chart the average of the monthly rainfall recorded at four places in Northeastern Saskatchewan during the months of June

Figure 3. A wheat field near Annaheim, Sask. Take-all is common in this district. The land is somewhat rolling and studded with little lakes and with groves of willow and poplar.

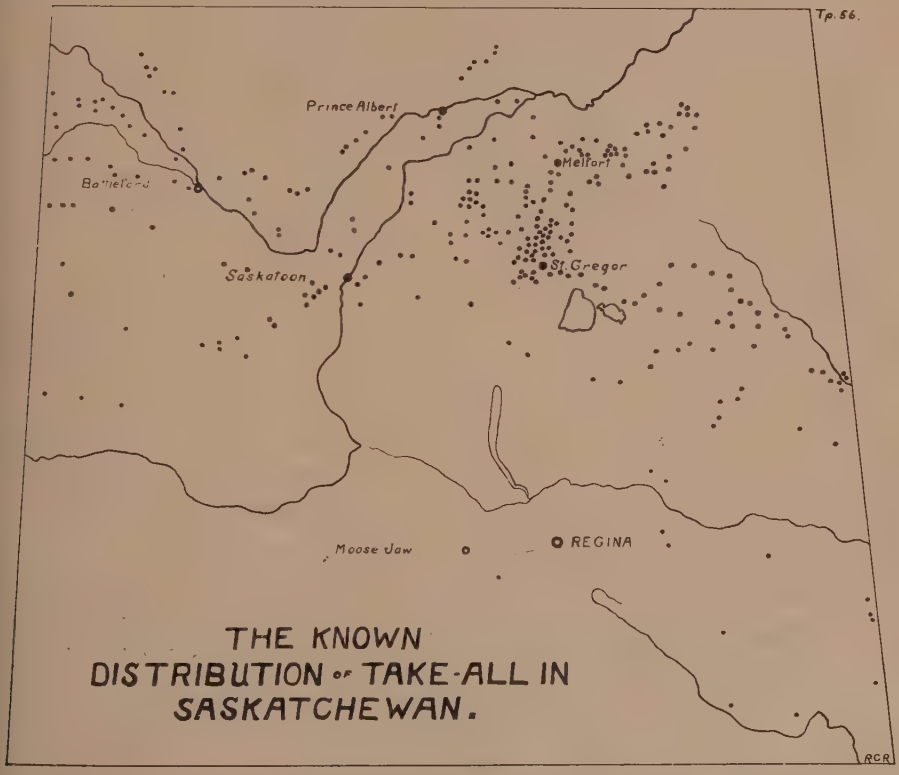



Figure 4. Map showing the known distribution of take-all in Saskatchewan up to, and including, the year 1929. Each dot represents a farm on which take-all has been found.

Figure 5. Samples of healthy and diseased wheat. On the left: a sheaf of 1(
healthy-looking plants collected in a field infested with take-all. On the right: a she
of 100 representative diseased plants from the same field.

July and August for the years 1923 to 1929. It can be seen that the rainfa
during these months in 1924 and 1926 was very low. In 1923, 1925 an
1927 the reverse was true. In 1923 take-all was first reported in this distri
and was probably fairly plentiful. Since then our annual field surveys hav
shown that take-all was relatively scarce in 1924 and 1926 whereas in 192
and 1927 it was quite prevalent (see remarks concerning the prevalence o
take-all in Saskatchewan in the annual reports of the Dominion Botanist fo
those years). During the summer of 1928 the Northeastern district o
Saskatchewan was drier on the average than many other sections of th
province but the precipitation varied considerably in this one district. Arour
Muenster, where the total rainfall for June and July was 6.22 inches, co
ditions were fairly moist and take-all was quite prevalent, while arou
Melfort, where the total precipitation was only 2.72 inches, the disease w
much less prevalent. In 1929 the Northeastern district enjoyed relative
favourable moisture conditions as compared with many other districts

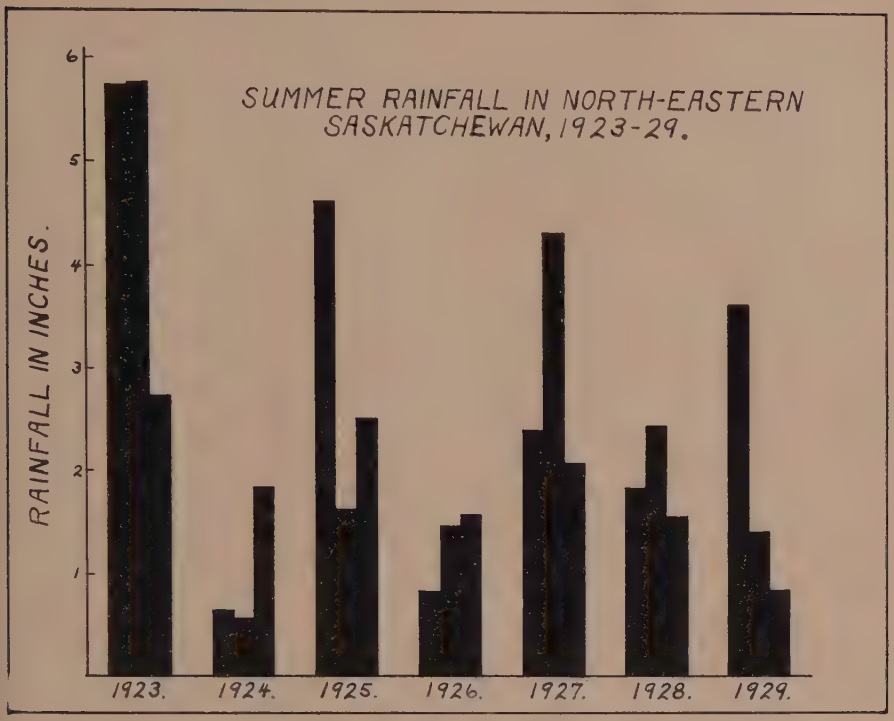



Figure 6. Chart showing the variations in the rainfall during June, July and August, 1923-29. This chart is based on the data for Northeastern Sask., published in the Reports of the Secretary of the Statistics Branch, Sask .Dept. of Agric., Regina, Sask., and on data obtained direct from the Director of the Meteorological Service, Toronto, Ont.

Saskatchewan. The rainfall for June at all four points where records were taken was over 3 inches. However, there was a decided falling off in precipitation as the summer advanced, the average for July being 1.42 inches and that for August being only 0.84 inches. Therefore, while the conditions were more favourable for the development of the disease than they were in many other parts of the province, yet it was so dry throughout July and the first part of August that comparatively few fields were badly affected and the signs of the disease were not pronounced on plants which were infected.

## Field Experiments

One of the chief phases of our problem has been the study of control measures. *O. graminis* has long proved to be a troublesome parasite of wheat in parts of Europe and Australia. There is a considerable body of literature from these and other regions concerning the trouble and we have profited by the experience of investigators in those countries. Since the disease affects both fall and spring wheat under a variety of climatic conditions and in countries where the cultural methods of wheat growing vary considerably, it is only reasonable to expect that the control measures suggested also vary considerably. For instance, in France the use of a dilute solution of sulphuric acid sprayed over the fields at the time infection is taking place has been recommended by a number of authorities (*12, 19, 27, 28*). They recommend spraying while the mycelium of the pathogen is in the outer

sheaths of the plant and claim that fairly satisfactory control is obtained when this is done. Of course in France the problem is complicated by the association of *Leptosphaeria herpotrichoides* de Not. with *O. graminis.* It does not appear as though this control measure is suited to our conditions and the cost of the treatment is comparatively high. Some investigators have claimed that the application of certain fertilizers greatly reduces the injury from take-all (*7, 22, 30, 32*). Burning off the stubble to destroy the spores of the fungus is a practice which has frequently been recommended as an aid in controlling this disease (*3, 9, 18*). Of the various other control measures suggested in the literature we are most interested in crop rotations. It seems to be fairly universally conceded that the preceding crop has a great effect upon the amount of disease in any one crop of wheat and many investigators from various countries have stressed the value of proper crop rotation to hold the disease in check (*5, 21, 26, 29, 34, 36, 37*). Because of this and because of what we learned from our field surveys in Saskatchewan we are making a special study of crop rotation as a means of controlling the malady in this country.

Thanks to the interest and generosity of two farmers living in North-eastern Saskatchewan, we have two experimental plots in districts where take-all is common. These are run on a co-operative basis. One of them is on the farm of Mr. Leo Helmink at St. Gregor and the other is on the farm of Mr. J. J. Hopkins at Melfort. After artificially inoculating the wheat for two seasons on the major part of the area of these plots a fairly thorough infestation of the soil was obtained and simple crop rotations are now being run on these fields. The rotation experiments have not been laid down long enough to yield conclusive data, but we hope to obtain valuable results from these in the course of a few years.

One corner of each of the above mentioned plots has been devoted to variety tests and dates of seeding experiments. One hundred different varieties of wheat were tested in the hope that some of them might prove to be resistant to take-all but they all became heavily diseased when artificially inoculated (see table 2). The Marquis strains proved to be no more susceptible than the other varieties tested. When one remembers that nearly 100 per cent of the plants are killed, at times, in diseased patches in fields of Marquis wheat, the possibility of developing resistant varieties from any of those tested does not seem very great. Five varieties each of barley and oats and two varieties of spring rye were tested along with the wheat varieties. Table 2 gives an idea of the relative susceptibility under field conditions of these various cereals to artificial inoculatons of *O. graminis.*

TABLE 2. *Effect of artificial inoculation with O. graminis, on cereals under field conditions. Results from St. Gregor plots for 1927.*

| Cereal | No. of varieties tested | Checks | | Inoculated | |
|---|---|---|---|---|---|
| | | Stunting | Dead | Stunting | Dead |
| | | | | % | % |
| Wheat | 100 | None | 11.4 | 50 (approx.) | 80.3 |
| Oats | 5 | None | 11.4 | 2 " | 2.7 |
| Barley | 5 | None | 5.0 | 33 " | 49.3 |
| Spring Rye | 2 | None | 12.25 | 2 " | 20.75 |

Note:—Stunting is based on the average height of the checks.

In the case of fall sown wheat, the date of seeding sometimes influences he severity of the disease considerably (*4, 12*). It was thought that the ame thing might be true in the case of spring wheat, and that the damage ight be lessened by controlling the date of seeding in ordinary farm practice. Therefore, dates of seeding tests are being run in our experiments. The ata secured so far are not sufficiently conclusive to warrant any recommenda-ions in this connection.

## Systematic Field Observations

In 1925 about two dozen fields in Northeastern Saskatchewan were hosen for annual study. In that year the wheat in these fields was distinctly uffering from take-all. No attempt was made to influence the farmers' hoice of crops for these fields in the succeeding years, but we inspected them nnually and studied the effects, on the disease, of the rotations which the armers were using. Table 3 gives our findings in a summarized form. At he same time, numerous other fields were studied for one or more years and vhat was learned from them corroborated the evidence of these special fields.

It appears from the following field study that take-all can be satisfactorily ontrolled in Saskatchewan by practising simple crop rotations. It has been ound that most of the noticeable damage occurs in fields which have been own continuously to wheat from the time the virgin sod was first broken, r else in wheat crops closely following brome grass or western rye grass see fields D, K and W in table 3). The first crop of wheat after a field of irgin sod is broken is seldom damaged to any great extent (see field M) nd the first crop of wheat following summer-fallow or a crop of oats rarely hows more than a trace of take-all (see fields I, Q and Y). It is interesting o note the difference in the amount of take-all appearing in different parts f certain fields which have been divided up and cropped differently during he course of this study (see fields G, R and X).

## Discussion

From our investigations it appears that the causal organism of take-all, *). graminis,* is indigenous to Western Canada. Experiments have shown that nany of our native grasses are quite susceptible, and the mycelium and peri-hecia of the pathogen have been found on certain grasses collected in the eld. At one time some investigators thought that take-all had been introduced nto North America from Australia but it seems much more probable that he fungus has existed in the prairie sod for years, parasitising certain of the rasses and fruiting on their dead remains. When the virgin sod is broken p and wheat is sown on the land, it is quite natural that the fungus should ourish and increase in amount, as wheat is one of its favourite hosts.

In districts where take-all is prevalent, noticeable damage may be xpected in the second and succeeding crops of wheat until the land is sum-ner-fallowed or sown to a less susceptible crop. Once a field has been sum-ner-fallowed or sown to oats, however, very little take-all is apt to appear in for several years, but in time it may reappear if wheat is again sown ntinuously. After land has been raising western rye grass or brome grass r a number of years and is then broken and sown to wheat, take-all some-

TABLE 3. *The effects of common crop rotations on take-all of wheat in Northeaste Saskatchewan.*

| Field | Location | 1925 | | 1926 | | 1927 | | 1928 | | 19 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Crop. | Inf. | Crop. | Inf. | Crop. | Inf. | Crop. | Inf. | Crop. |
| A | St. Gregor | W | m | W | l | O | o | W | t | O |
| B | " | W | m | O | o | O | o | S | – | W |
| C | " | W | l | W | l | O | o | S | – | W |
| D | Annaheim | W | ? | W | ? | W | h | O | o | W |
| E | Englefeld | W | l | W | l | S | – | W | t | W |
| F | St. Gregor | W | h | W | l | S | – | W | t | O |
| G | " | W | h | O | o | S | – | W | t | W |
| | | | | | | W | t | S | – | W |
| H | " | W | h | W | m | O | o | W | t | B |
| I | Muenster | W | m | S | – | W | t | O&B | o | W |
| J | Carmel | W | m | W | l | S | – | W | o | W |
| K | Annaheim | W | h | W | m | W | h | S | – | W |
| L | " | W | m | W | l | W | m | S | – | W |
| M | " | brea king | | W | t | W | m | W | m | S |
| N | " | W | m | W | l | B&O | o | S | – | W |
| O | " | W | h | B&O | o | B | o | W | m | W |
| | | | | | | | | S | – | W |
| P | Naicam | W | m | W | l | O | o | O | o | W |
| Q | Cudworth | W | h | S | – | W | t | W | l | S |
| R | St. Brieux | W | m | O | o | W | l | O | o | W |
| | | | | W | l | W | h | B | o | B&O |
| S | Resource | W | h | B | – | W | t | W | l | B |
| T | " | W | h | O | o | O | o | O | o | O |
| U | Valparaiso | W | h | W | m | O | o | S.C. | o | O |
| | | | | | | | | WRG | ? | WRG |
| V | Star City | W | h | O | o | S | – | W | o | W |
| W | Ethelton | W | h | B.G. | ? | break ing | | W | h | W |
| X | Valparaiso | W | m | W | m | W | h | O | o | S |
| | | | | | | O | o | W | t | O |
| | | | | | | S | – | W | l | |
| Y | " | W | h | O | o | W | t | O | o | S |
| | | | | | | | | | | W |
| Z | Melfort | W | m | O | o | W | o | O | o | S |

Crops—W-wheat: O-oats: B-barley: B.G.-brome grass: Sw. C-sweet clover: W.R.G.-rye grass: S-summer fallow.

*Severity of infection.*

o—none evident.
t—trace; several plants bearing take-all symptoms.
l—light; about 1%, by estimate, of plants in whole field infected.
m—moderate; 2-10%, by estimate, of plants in whole field infected.
h—heavy; over 10%, by estimate, of plants in whole field infected.

times causes severe injury. Even in districts where it is common, take not usually noticeable in the majority of older fields because most of have undergone sufficient rotation of crops and summer-fallowing them largely of the disease.

The actual loss caused by take-all over a large district is ha estimate accurately. We have shown, however, that an approximation damage in any particular field may be reached by making an estimate percentage of the crop which is stunted and then multiplying this by four-fifths, as it was found that the diseased plants produced only one-fifth of the normal yield (see table 1). The amount of take-all i one district varies greatly with the wetness of the season. In the districts where the larger proportion of the land is relatively new, the d is apt to be greater than in districts which have been settled for a

period. The collective damage throughout Saskatchewan in wet years is at present very great.

The one redeeming feature of the disease, as we know it, is that it can be combatted by a practicable method of control. Simple rotations of crops already grown in Saskatchewan afford an economical and practical as well as efficient method of dealing with this trouble. Therefore, the following recommendations are made, but it must be borne in mind that they do not necessarily apply to the other types of root-rot which attack wheat in Saskatchewan. Moreover the rotations suggested are not recommended for universal or permanent use, but merely to reduce the amount of take-all present in fields where it is known to be present or likely to develop. After such fields have been cropped for a few years in the manner recommended, it is believed that rotations, such as those designed for the district by agronomists, can be used without further trouble from take-all. In districts where take-all is prevalent wheat should not be sown continuously on new land for the first few years, but a rotation used such as the following: *breaking, wheat, oats, wheat, summer-fallow.* If a field is already infested with take-all, it should be handled in one of the following ways, depending upon the circumstances: (a) if the field is comparatively free from weeds, sow oats on it for a year or two and then summer-fallow it and (b) if it is weedy, and other considerations make it seem advisable to summer-fallow the land, do so the following year and try wheat on it the succeeding year. It is not definitely known how many years it takes to starve out *O. graminis* from land which is not producing any of the hosts of the fungus, but it appears that one or two years is sufficient to reduce it to a condition in which it no longer causes appreciable injury to wheat, unless the latter is again sown for several years in succession.

Certain other things should be borne in mind when one is attempting to eradicate take-all from a field. *O. graminis* appears to live over on creeping-rooted grasses and volunteer wheat when these are present in a field infested with the fungus. Therefore, great care should be taken to kill volunteer wheat and such grasses as *Agropyron repens* (L) Deauv., *A. Smithii* Rydb., *Torresia odorata* (L) Hitchc. and *Bromus inermis* Leyss. in such fields. It is not considered safe to sow wheat after barley or rye if the land has recently been infested with *O. graminis* but the injury is not liable to be so severe as it is in wheat following a diseased crop of wheat. Flax, corn, sunflowers, sweet-clover and potatoes are other crops which may be used instead of oats for the purpose of reducing take-all infestation.

Other methods of control such as burning the stubble, applying fertilizers to the land, or treating the standing crop with sulphuric acid may eventually prove to be economically profitable but at present the rotation of crops is the only method which we can confidently recommend.

## Summary

1. Take-all of wheat was first reported in Canada from Saskatchewan in 1923. It is now known to occur commonly in certain districts throughout the Prairie Provinces. The causal organism, *Ophiobolus graminis* Sacc., is believed to be indigenous to Western Canada.

2. The disease has a long history and is known to be world-wide i its distribution.

3. The disease is described and a method is given of distinguishing from all other root-rots of wheat which are known to occur in Saskatchewar

4. Its distribution in Saskatchewan is confined mainly to the semi wooded areas.

5. Where prevalent it is a disease of considerable economic importance especially on comparatively new land which is being cropped continuously t wheat.

6. The severity of the disease fluctuates considerably from year t year depending largely on the amount of rainfall. In comparatively we years it is relatively prevalent and in comparatively dry years it is relativel scarce. Moist conditions late in the growing season tend to develop th signs of the disease on the host.

7. Field experiments are being conducted to ascertain the effect o crop rotations and date of seeding on the subsequent development of th disease.

8. Systematic field surveys carried on annually from 1924 to 1929 hav indicated that simple crop rotations control the disease satisfactorily.

9. Certain measures, of which suitable crop rotation is the chief, ar suggested for the control of take-all.

## Acknowledgements

The writer gratefully acknowledges the kind assistance and advic which he has received from time to time from other members of the staff He is also indebted to certain members of the Biology Department, Universit of Saskatchewan for part of the data concerning the distribution of take-al in Saskatchewan.

## LITERATURE CITED

1. Anonymous. Pietin o mal del pie de los cereales. Min. Agric. Nac. (Bueno Aires) Secc. Prop. e Inform. Circ. 731, 1927. Rev. Myc. *7*: 5: 314, 1928.
2. Bensaude, Mathilde. Notes on wheat diseases in Portugal, Bol. Soc. Broterian *6* (Ser. 2), 41 pp., 1 map, 1929. Rev. App. Myc. *8*: 10: 637, 1929.
3. Brittlebank, C. C. Green manurial crops and take-all. Jour. Dept. Agric. Victori *17*: 171-173, 1919.
4. Brunehant. La production du Blé en 1926. Comptes rendus Acad. d'Agric. d France *12*: 29: 812-822, 1926. Rev. App. Myc. *6*: 2: 84, 1927.
5. Carne, W. M. and Campbell, J. G. C. Take-all of wheat and similar diseases c cereals. Western Australia Dept. Agric. Bul. No. 119, pp. 3-10, 1924.
6. Cunningham, G. H. New Zealand: activities in the field of plant pathology i 1927. Internat. Bul. of Plant Protection *1*: 10: 157-158, 1927. Rev. App. Myc. 7 4: 224, 1928.
7. Darnell-Smith, G. P. Green vitriol (ferrous sulphate) as a preventative fo take-all. Agric. Gaz. New South Wales *27*: 134, 1916.
8. Dastur, J. F. Annual report on the Mycological section for the year ending March 1927. Dept. Agric., Central Provinces and Berar, for the years 1926-27, 192 Rev. App. Myc. *7*: 8: 492, 1928.
9. Fish, S. Take-all in wheat. Field observations at Murrayville. Jour. Dep Agric. Victoria *25*: 7: 423-425, 1927. Rev. App. Myc. *6*: 12: 720, 1927.

10. Fraser, W. P. Take-all of wheat in Western Canada. Phytopath. *14*: 7: 347, 1924.
11. ———— Simmonds, P. M. and Russell, R. C. The take-all disease in Canada. (Abst.) Phytopath. *16*: 1: 80-81, 1926.
12. Gaudineau, Mlle and Guyot, L. De quelques facteurs qui influencent le développement de la maladie du piétin du Blé. Rev. Path. Vég. et Ent. Agric. *12*: 4: 317-342, 1925. Rev. App. Myc. *5*: 7: 415, 1926.
13. Gaumann, E. Die wirtschaftliche Bedeutung unserer wichtigeren Pflanzenkrankheiten. Landw. Jahrb. der Schweiz *41*: 2: 319-324, 1927. Rev. App. Myc. *6*: 7: 429, 1927.
14. Gram, E., Jorgensen, C. A. and Rostrup, S. Oversigt over sygdomme hos landbrugets og havebrugets kulturplanter i Tidsskr. for planteavl *33*: 5: 781-841, 1927. Rev. App. Myc. *7*: 4: 222, 1928.
15. Gussow, H. T. Take-all, flag smut and ear cockle of wheat. Agric. Gaz. Canada *6*: 7: 1, 1919.
16. Heald, F. D. Thirty-third annual report, Wash. Agric. Exp. Sta. for the fiscal year ended June 30th, 1923. Rev. App. Myc. *3*: 6: 320, 1924.
17. Kassel, G. Der Weizenhalmtöter (*Ophiobolus herpotrichus*). Illus. Landw. Zeit. *47*: 31: 409, 1927. Rev. App. Myc. *7*: 2: 86, 1928.
18. Kirby, R. S. The take-all disease of cereals and grasses caused by *Ophiobolus cariceti* (Berkeley and Broome) Saccardo. Cornell Univ. Agric. Exp. Sta. Mem. 88, 45 pp., 1925.
19. Kuhnholtz-Lordat, G. Traitement des céréales par l'acide sulfurique. Prog. Agric. et Vitic. *87*: 6: 138, 1927. Rev. App. Myc. *6*: 7: 403, 1927.
20. McAlpine, D. Take-all in wheat. Jour. Dept. Agric. Victoria *1*: 74-80, 1902.
21. ———— Take-all and whiteheads in wheat. Jour. Dept. Agric. Victoria *2*: 5: 410-426, 1904.
22. Parisot, M. Le Piétin du Blé. Compt. Rend. Acad. Agric. France *12*: 20: 565-577, 1926.
23. Petri, L. Rassegna dei casi fitopatologici più notevoli osservati nel 1926. Boll. R. Staz. Pat. Veg. *7*: 1: 1-45, 2 figs., 1927. Rev. App. Myc. *6*: 7: 394, 1927.
24. Preston, N. C. Pt. I. Report of the advisory mycologist. March, 1927-April, 1928. Rept. Advisory Dept., Harper Adams Agric. Coll., Newport, Salop *3*: 4-7, 1928. Rev. App. Myc. *7*: 11: 701, 1928.
25. Prillieux, E. and Delacroix, G. La maladie du pied du Blé, causée par *l'Ophiobolus graminis* Sacc., Bul. Soc. Mycol. France. *6*: 110-113, 1890.
26. Putterill, V. A. Plant diseases in the Western Cape Province, "Vrotpootjie" or "Take-all" of wheat, Jour. Dept. Agric. Union of South Africa *8*: 602-612, 1924.
27. Rabate, E. Action de l'acide sulfurique dilué dans les champs de céréals. Jour. d'Agric. Prat. *88*: 51: 497-499, 1924. Rev. App. Myc. *4*: 4: 213, 1925.
28. ———— Action de l'acide sulfurique sur le piétin du Blé. Jour. d'Agric. Prat. *91*: 7: 133-135, 1927. Rev. App. Myc. *6*: 5: 280, 1927.
29. Richardson, A. E. V. Wheat and its cultivation. Dept. Agric. Victoria, Australia Bul. No. 55 (N.S.) pp. 119-120, 1925.
30. Rosen, H. R. and Elliot, J. A. Pathogenicity of *Ophiobolus cariceti* in its relationship to weakened plants. Jour. Agric. Res. *25*: 351-358, 1923.
31. Russell, R. C. Take-all. A destructive disease of wheat. Dom. Can. Dept. Agric. Pamphlet No. 85 (N.S.), 1927.
32. Samuel, G. Take-all investigations, I. Jour. Dept. Agric. South Australia *27*: 5: 438-442, 1923.
33. Sanford, G. B. Important soil-borne diseases of crops in Western Canada. *Scientific Agric. 7*: 8: 292-294, 1927.
34. Sewell, M. C. and Melchers, L. E. The effect of rotation and tillage on foot-rot of wheat in Kansas, 1920-1924. Jour. Amer. Soc. Agron. *16*: 768-771, 1924.
35. Summers, W. L. Take-all and white-heads in wheat crops. Jour. Dept. Agric. South Australia *7*: 297-299, 1903.
36. Sutton, G. L. Take-all. Practical methods for its eradication and control. Agric. Gaz. New South Wales *22*: 161-163, 1911.
37. ———— Take-all, septoria, rust and wheat mildew. Western Australia Dept. Agric. Bul. *69*: 3-10, 1920.
38. Tedin, O. Rotdödarens härjningar pa Skanes Vetefält. Landtmannen *10*: 36: 705-707, 1927. Rev. App. Myc. *7*: 3: 155, 1928.

39. Van Poeteren, N. Verslag over de werkzaamheden van den Plantenzeiktenkundigen Dienst in het jaar 1925. Versl. en Meded. Plantenzeiktenkundigen Dienst te Wageningen *44*: 124 pp. 1926. Rev. App Myc. *6*: 8: 461, 1927.

40. Wahl, B. Bericht über die Tätigkeit der Bundesanstalt für Pflanzenschutz in Wien im Jahre 1924. Zeitschr. Landw. Versuchswesen in Deutschösterreich, 28 pp., 1925. Rev. App. Myc. *5*: 4: 210, 1926.

# VARIATION IN THE QUALITY OF WHEAT GROWN IN REPLICATE PLOTS *

R. Newton and J. G. Malloch †
*University of Alberta, Edmonton, Alberta*

[Received for publication March 29, 1930].

## Introduction

The unreliability of yields obtained from single plots is fully recognized and various systems of replication are employed in an effort to obtain accurate yield data in field experiments. In dealing with quality in wheat, however, there has been a tendency to assume that climatic factors are largely responsible for the variation in quality and to neglect the possible effect of soil heterogeneity. In recent years the importance of soil factors in determining the quality of wheat has been demonstrated. It is the purpose of this paper to direct attention to the variation in the quality of wheat grown in replicate plots and to the need for special precaution in sampling for quality tests.

## Protein Content and Kernel Texture of Samples from Raymond, Alberta

In 1927 the results of wheat variety tests made at the Agricultural School, Raymond, were reported to the Alberta Committee on Varietal Zonation. Mr. J. P. Ficht, at that time agronomist at the School, noticed considerable variation between the kernel texture of the wheat from the replicate plots of each variety. He was good enough to send us samples from these plots.

The field on which these plots were grown is level and uniform in appearance. The space covered by the plots was only 175 links by 220 links, each plot being 1/200 acre in area. The plots were arranged in four series as shown later in diagram 1.

The samples from these plots were analyzed for protein and classified on the basis of kernel texture. A thousand kernels were taken for this classification. Kernels were classified as vitreous only when they were completely free from starchy spots, and as starchy only when they were completely starchy. All others were classified as piebald. As a rule, the classification was made on the basis of external appearance, but in doubtful cases the kernels were cut and the cut surface examined.

The results are given in table 1 and include the rate of yield of each plot to make possible a comparison of its variations with those of protein content. The values for protein are reported on the dry basis (both in this table and throughout this paper). The probable errors of the protein averages were calculated by the deviation-from-the-mean method (*1*); the probable error in per cent for the whole series is $\pm$ 7.49. In the column headed "Spread" is given the difference in protein content between the highest and lowest plots of each variety.

*Paper No. 13 of the Associate Committee on Grain Research, National Research Council of Canada.

†Professor of Field Crops and Research Assistant, respectively.

TABLE 1. *Protein content and kernel texture in replicate plots—Raymond, 1927.*

| Variety | Plot No. | Yield per acre | Protein in wheat | | | Kernel texture | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | By plots | Spread | Co-eff. of variation | Vitreous | Piebald | Starchy | Co.-eff. of variation (vitreous) |
| | | bushels | % | % | | % | % | % | |
| Early Triumph | 3 | 57.0 | 10.0 | 2.2 | 8.8 | 8.8 | 37.9 | 53.3 | 78.7 |
| | 21 | 48.5 | 11.7 | | | — | — | — | |
| | 28 | 61.0 | 9.5 | | | 0.2 | 5.9 | 93.9 | |
| | 46 | 77.0 | 11.5 | | | 4.2 | 56.6 | 39.2 | |
| | Av. | | 10.7 ± .40 | | | 4.4 | 33.5 | 62.1 | |
| Garnet | 1 | 52.5 | 10.5 | 3.4 | 11.2 | 81.7 | 14.1 | 4.2 | 20.8 |
| | 19 | 54.0 | 11.9 | | | 93.9 | 5.3 | 1.4 | |
| | 30 | 62.0 | 10.9 | | | 51.6 | 43.8 | 4.6 | |
| | 48 | 56.0 | 13.9 | | | 89.7 | 9.8 | 0.5 | |
| | Av. | | 11.8 ± .44 | | | 79.1 | 18.2 | 2.7 | |
| Huron | 10 | 55.5 | 14.0 | 3.7 | 13.2 | 28.9 | 66.9 | 4.2 | 123.9 |
| | 16 | 59.5 | 10.3 | | | 1.9 | 15.0 | 83.1 | |
| | 34 | 66.5 | 10.6 | | | 3.7 | 16.4 | 79.9 | |
| | 39 | 66.0 | 10.8 | | | 2.1 | 22.8 | 75.1 | |
| | Av. | | 11.4 ± .43 | | | 9.2 | 30.3 | 60.6 | |
| Kitchener | 9 | 50.5 | 13.2 | 3.5 | 12.3 | 40.6 | 57.1 | 2.3 | 160.7 |
| | 15 | 66.5 | 9.7 | | | 0.0 | 0.7 | 99.3 | |
| | 33 | 74.5 | 10.2 | | | 0.6 | 7.8 | 91.6 | |
| | 40 | 76.5 | 10.7 | | | 1.8 | 14.4 | 83.8 | |
| | Av. | | 11.0 ± .41 | | | 14.3 | 20.0 | 69.2 | |
| Marquis | 7 | 58.0 | 12.9 | 2.6 | 8.3 | 12.4 | 65.9 | 21.7 | 61.7 |
| | 13 | 58.5 | 10.3 | | | 2.6 | 13.0 | 84.4 | |
| | 31 | 70.0 | 12.0 | | | 15.4 | 48.6 | 36.0 | |
| | 42 | 71.0 | 11.3 | | | 4.3 | 48.3 | 47.4 | |
| | Av. | | 11.6 ± .43 | | | 8.7 | 44.0 | 47.4 | |
| Marquis 10B | 8 | 52.5 | 13.2 | 2.8 | 8.8 | 23.9 | 64.9 | 11.2 | 113.0 |
| | 14 | 66.0 | 10.4 | | | 0.9 | 12.0 | 87.1 | |

| Variety | Plot No. | Yield per acre | Protein in wheat | | | Kernel texture | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | By plots | Spread | Co-eff. of variation | Vitreous | Piebald | Starchy | Co.-eff. of variation (vitreous) |
| | | bushels | % | % | | % | % | % | |
| Red Bobs 222 | 2 | 61.0 | 9.9 | 2.3 | 9.5 | 5.3 | 22.6 | 72.1 | 122.1 |
| | 20 | 51.0 | 11.8 | | | 37.9 | 39.5 | 22.6 | |
| | 29 | 64.5 | 9.9 | | | 1.7 | 19.6 | 78.7 | |
| | 47 | 78.5 | 12.1 | | | 4.1 | 74.8 | 21.1 | |
| | Av. | | 10.9 ± .41 | | | 12.2 | 39.1 | 48.6 | |
| Red Fife | 12 | 49.0 | 15.4 | 4.9 | 15.1 | 14.4 | 67.2 | 18.4 | 120.0 |
| | 18 | 56.0 | 11.4 | | | 2.7 | 47.6 | 49.7 | |
| | 36 | 72.5 | 11.9 | | | 1.0 | 25.9 | 73.1 | |
| | 37 | 48.0 | 10.5 | | | 0.8 | 12.4 | 86.8 | |
| | Av. | | 12.3 ± .46 | | | 4.7 | 38.3 | 57.0 | |
| Renfrew | 11 | 57.5 | 13.3 | 3.5 | 12.1 | 18.2 | 35.6 | 46.2 | 127.2 |
| | 17 | 64.5 | 11.5 | | | 11.1 | 9.8 | 89.1 | |
| | 35 | 76.5 | 10.3 | | | 1.7 | 9.4 | 88.9 | |
| | 38 | 60.5 | 9.8 | | | 1.6 | 4.7 | 93.7 | |
| | Av. | | 11.2 ± .42 | | | 5.7 | 14.9 | 79.5 | |
| Reward | 5 | 50.5 | 13.0 | 3.0 | 8.2 | 20.8 | 72.8 | 6.4 | 12.8 |
| | 23 | 51.5 | 14.5 | | | | | | |
| | 26 | 52.5 | 11.5 | | | 28.6 | 2.2 | 29.2 | |
| | 44 | 58.5 | 13.1 | | | 25.2 | 64.4 | 10.4 | |
| | Av. | | 13.0 ± .49 | | | 24.9 | 59.8 | 15.3 | |
| Supreme | 4 | 61.5 | 9.4 | 2.3 | 10.8 | 0.4 | 4.3 | 95.3 | 155.5 |
| | 22 | 57.5 | 11.6 | | | 11.4 | 51.9 | 36.7 | |
| | 27 | 63.0 | 9.3 | | | 0.2 | 3.4 | 96.4 | |
| | 45 | 74.5 | 10.7 | | | 0.2 | 7.7 | 92.1 | |
| | Av. | | 10.2 ± .38 | | | 3.1 | 16.8 | 80.1 | |
| Fisher's No. 1 | 6 | 68.0 | 11.2 | 3.3 | 10.3 | 10.6 | 29.9 | 59.5 | 81.3 |
| | 24 | 56.0 | 13.1 | | | 59.8 | 35.6 | 4.6 | |
| | 25 | 62.5 | 9.8 | | | | | | |
| | 43 | 78.0 | 11.6 | | | 6.7 | 20.4 | 72.9 | |
| | Av. | | 11.4 ± .43 | | | 25.7 | 28.6 | 45.7 | |

It is not the intention to discuss the variations in yield per acre of the replicate plots; this problem has been adequately dealt with by many writers. The yields are listed in table 1 (and in tables 2 and 4) merely to show that variations in yield and protein content have no necessary relation. This can readily be seen by inspection of the two sets of figures for any variety, although the observations are not numerous enough to make possible the calculation of correlation coefficients. There is in fact no correlation between the yield and protein content of the entire series, but a comparison of this sort seems not to be justified, since inherent varietal differences in yield and protein content are arbitrary factors interfering with the normal distribution of values which might result from soil heterogeneity alone.

The distribution of the protein values over the entire block is shown in diagram 1. The plots number consecutively from left to right along each line, beginning with plot 1 in the upper left-hand corner and ending with plot 48 in the lower right-hand corner. Reference to table 1 will make it possible to identify any variety. The figures show a definite tendency towards lower protein at one end of the block, which must be attributed to soil heterogeneity.

DIAGRAM 1. *Variation in protein content of wheat in test plots at Raymond, Alberta, 1927.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.5 | 9.9 | 10.0 | 9.4 | 13.0 | 11.2 | 12.9 | 13.2 | 13.2 | 14.0 | 13.3 | 15.4 |
| 10.3 | 10.4 | 9.7 | 10.3 | 11.5 | 11.4 | 11.9 | 11.8 | 11.7 | 11.6 | 14.5 | 13.1 |
| 9.8 | 11.5 | 9.3 | 9.5 | 9.8 | 10.9 | 12.0 | 11.2 | 10.2 | 10.6 | 10.3 | 11.9 |
| 10.5 | 9.8 | 10.8 | 10.7 | — | 11.3 | 11.6 | 13.1 | 10.7 | 11.5 | 12.1 | 13.9 |

There is an average spread in protein content between the high and low plots of each variety of 3.2 per cent, with a maximum of 4.9 per cent and a minimum of 2.2 per cent. On the other hand, the spread between the average protein content of the highest variety (Reward) and that of the lowest variety (Supreme) is 2.3 per cent. Only one variety (Early Triumph) has a spread between its highest and lowest plots less than this figure. In other words, the differences due to soil heterogeneity are greater than the differences due to variety. Since the probable errors of the means of the varietal protein contents vary from 0.38 to 0.50, there are in fact only a few cases in which the differences between varieties can be regarded as statistically significant.

There is little doubt that in most circumstances differences in protein content of over 1 per cent would be considered significant. It is very important therefore to find that such differences can arise between plots of one variety grown in close proximity to one another, and hence subject to

identical climatic environment, and that the variations can be large enough to invalidate varietal comparisons based on the differences between the means of four plots.

Differences that are fully as striking as those in protein content are to be found in the classification by kernel texture. For instance, there is a variation in the percentage of vitreous kernels in Kitchener from 0.0 to 40.0 per cent. The figures in table 1 show also the lack of clear-cut relationship between protein content and physical characteristics of the kernels, a problem which has been discussed previously (*2*).

The coefficient of variability ranges from 8.2 to 15.1 for protein, and from 12.8 to 160.7 for number of vitreous kernels. Even the lower values indicate a high variation. It is evident that the results from single plots are totally unreliable.

## Protein Content of Samples from University of Alberta Variety Plots

In view of the results with the preceding series, it was decided the next year to analyze separately samples of each of the replicates in our Edmonton variety tests. At the same time, in connection with another project, samples were taken from the bulked replicates and analyzed for protein.

The plots consisted each of 14 rows, 1 link apart, 100 links long, and were arranged in two series running north and south. Both series were numbered starting at the north from 1 to 29, and from 30 to 58. The results, aranged by varieties, are given in table 2.

It will be seen in table 2 that the spreads in protein content are much less in this case than in the Raymond series. The average spread for all varieties is 1.1 per cent, with a maximum of 1.6 per cent and a minimum of 0.3 per cent. The spread in the check plots of Marquis 0.15 is 1.0 per cent. But for the low protein content of the wheat from plot 58, this spread would have been still less; it is 0.6 per cent for the other nine check plots.

The coefficients of variation in this series are also lower than those in the Raymond series. They range from 1.0 to 5.8, but with three exceptions they are all below 3. This indicates a very good agreement between the replicate plots. The probable errors of the means are correspondingly low, ranging from 0.10 to 0.19, and the probable error in per cent for the whole series is only $\pm$ 1.9.

It would appear that the land on which these samples were grown is sufficiently uniform so that the differences between the means of the varietal protein contents may be accepted with confidence. However, the spreads and coefficients of variation are large enough to show that the results from single plots are not trustworthy.

The fluctuations in the yield of replicate plots are surprisingly great, considering the apparent uniformity of the land indicated by the protein values, and suggest the need of further investigation to resolve the proportionate effects of soil heterogeneity and other contributing factors. There is again no relation between yield and protein content.

TABLE 2. *Protein content in replicate plots—Edmonton 1928.*

| Variety | Plot No. | Yield per acre | Protein in wheat | | | |
|---|---|---|---|---|---|---|
| | | | By plots | Spread | Average | Co-eff. of variation |
| | | bushels | % | % | % | |
| Marquis 0.15 (check) | 1 | 62.5 | 16.0 | 1.0 | 16.2 ± .10 | 2.4 |
| | 8 | 51.1 | 16.3 | | | |
| | 15 | 42.7 | 16.3 | | | |
| | 22 | 40.2 | 16.2 | | | |
| | 29 | 47.0 | 16.5 | | | |
| | 30 | 49.2 | 16.2 | | | |
| | 37 | 46.7 | 16.2 | | | |
| | 44 | 45.2 | 16.2 | | | |
| | 51 | 38.9 | 16.6 | | | |
| | 58 | 50.2 | 15.6 | | | |
| Garnet | 2 | 52.1 | 16.3 | 1.0 | 15.8 ± .14 | 3.6 |
| | 16 | 53.0 | 15.3 | | | |
| | 31 | 43.6 | 15.7 | | | |
| | 45 | 41.1 | 15.7 | | | |
| Red Bobs 222 | 3 | 58.1 | 15.4 | 1.6 | 15.6 ± .14 | 5.8 |
| | 17 | 52.7 | 14.8 | | | |
| | 32 | 56.0 | 16.4 | | | |
| | 46 | 52.7 | 15.8 | | | |
| Early Triumph | 4 | 60.9 | 15.9 | 0.7 | 16.2 ± .14 | 2.9 |
| | 18 | 51.0 | 15.8 | | | |
| | 33 | 62.6 | 16.4 | | | |
| | 47 | 57.8 | 16.5 | | | |
| Supreme | 5 | 55.7 | 15.0 | 1.1 | 14.6 ± .14 | 1.5 |
| | 19 | 48.3 | 14.2 | | | |
| | 34 | 56.7 | 14.1 | | | |
| | 48 | 49.8 | 15.2 | | | |
| Ruby | 6 | 41.8 | — | | | |
| | 20 | 41.7 | 16.9 | 0.9 | 17.3 ± .19 | 1.2 |
| | 35 | 48.3 | 17.8 | | | |
| | 49 | 45.0 | 17.1 | | | |
| Reward | 7 | 45.4 | 19.0 | 2.3 | 18.6 ± .17 | 2.9 |
| | 21 | 44.0 | 17.0 | | | |
| | 36 | 46.8 | 19.3 | | | |
| | 50 | 56.2 | 19.1 | | | |
| Marquis 10B | 9 | 51.2 | 16.6 | 0.5 | 16.4 ± .15 | 2.1 |
| | 23 | 41.2 | 16.1 | | | |
| | 38 | 43.2 | 16.3 | | | |
| | 52 | 41.9 | 16.6 | | | |
| Marquis 3641 | 10 | 43.8 | 16.3 | 0.3 | 16.2 ± .15 | 1.3 |
| | 24 | 41.8 | 16.4 | | | |
| | 39 | 40.0 | 16.1 | | | |
| | 53 | 37.7 | 16.1 | | | |
| Kitchener | 11 | 41.9 | 15.0 | 0.9 | 14.4 ± .13 | 1.0 |
| | 25 | 39.7 | 14.3 | | | |
| | 40 | 52.7 | 14.1 | | | |
| | 54 | 44.8 | 14.3 | | | |
| Huron | 12 | 47.3 | 16.5 | 1.6 | 15.6 ± .14 | 2.1 |
| | 26 | 53.0 | 15.1 | | | |
| | 41 | 57.4 | 16.0 | | | |
| | 55 | 56.3 | 14.9 | | | |
| Renfrew | 13 | 55.2 | 15.8 | 1.3 | 15.0 ± .14 | 1.7 |
| | 27 | 36.4 | 15.2 | | | |
| | 42 | 52.1 | 14.5 | | | |
| | 56 | 50.4 | 14.6 | | | |
| Red Fife | 14 | 41.7 | 15.4 | 1.4 | 15.2 ± .14 | 1.9 |
| | 28 | 44.3 | 15.7 | | | |
| | 43 | 38.1 | 15.2 | | | |
| | 57 | 38.3 | 14.3 | | | |

## Errors in Sampling and in Determining Protein Content

The variation between the individual plots of any variety may be attributed either to soil heterogeneity or to errors in sampling the crop or in determining the protein content of the samples. Data were obtained in the course of another investigation with the Edmonton 1928 samples which give a measure of the latter kind of errors. The samples from the individual plots were bulked and divided into four portions of about six pounds each. One of these was retained at the University of Alberta and the others were sent respectively to the University of Manitoba, the University of Saskatchewan and the Dominion Grain Research Laboratory. Each laboratory took a sub-sample for protein analysis. The results of these four analyses are given in table 3, together with their coefficients of variation, and for convenient comparison the coefficients of variation of the four replicate plots are carried forward from table 2.

Table 3. *Variation in results of replicate determinations of protein content in wheat varieties grown at Edmonton, 1928.*

| Variety | Protein content | | | | Coefficient of variation | |
|---|---|---|---|---|---|---|
| | Lab. A | Lab. B | Lab. C. | Lab. D | Replicate determinations | Replicate plots |
| | % | % | % | % | | |
| Marquis 0.15 | 16.4 | 16.3 | 16.4 | 16.2 | 0.5 | 2.4 |
| Garnet | 16.5 | 16.3 | 16.4 | 16.4 | 0.4 | 3.6 |
| Red Bobs 222 | 16.1 | 16.0 | 16.4 | 16.1 | 1.0 | 5.8 |
| Early Triumph | 16.5 | 16.1 | 16.5 | 16.1 | 1.2 | 2.9 |
| Supreme | 15.0 | 14.1 | 15.1 | 14.9 | 2.7 | 1.5 |
| Ruby | 17.8 | 17.7 | 17.9 | 17.6 | 0.7 | 1.2 |
| Reward | 19.2 | 18.9 | 19.3 | 18.7 | 1.3 | 2.9 |
| Marquis 10B | 16.6 | 16.1 | 16.9 | 16.6 | 1.8 | 2.1 |
| Marquis 3641 | 16.6 | 16.3 | 16.5 | 16.1 | 1.2 | 1.3 |
| Kitchener | 14.8 | 14.7 | 14.8 | 14.7 | 0.5 | 1.0 |
| Huron | 15.8 | 15.7 | 15.8 | 15.8 | 0.3 | 2.1 |
| Renfrew | 14.7 | 14.7 | 14.9 | 14.3 | 1.5 | 1.7 |
| Red Fife | 14.8 | 14.9 | 15.3 | 14.7 | 1.6 | 1.9 |

From the point of view taken in this paper, the crucial comparison in table 3 is that between the coefficients of variation for replicate determinations and for replicate plots. In making this comparison, however, there are two conditions to keep in mind. The replicate determinations were made in different laboratories and minor differences of method and technique exaggerate the apparent variability of the results. Those reported by laboratories A and C, for example, are almost consistently higher than those of laboratories B and D. On the other hand the coefficients of variation of the replicate plots are based on results from a very uniform piece of land and on determinations made in a single laboratory. These conditions operate to make the first set of coefficients higher than normal and the second set lower than normal. In spite of this, it will be seen that in only one case is the variation between the results of the four laboratories greater than the variation between plots. In this case (Supreme) the result from laboratory B is clearly out of line, and in any ordinary comparison would be discarded. The results as a whole show that the variation due to the combined

effect of errors in sampling and in determining the protein content is no equal to that attributable to soil heterogeneity.

## Yield and Quality of Wheat Grown in Duplicate Plots at Lethbridge

For several years we have obtained wheat samples from the Experimenta Farm at Lethbridge through the courtesy of Messrs. Fairfield and Palmer The quality of these samples has been studied extensively. In table 4 ar given some of the results obtained with samples from duplicate plots in th series of 1926 and 1927.

Table 4. *Yield and quality of wheat from duplicate plots—Lethbridge 1926 and 1927.*

| Sample No. | Yield per acre | Grade | Protein in wheat | Ash in wheat | Yield of pat. flour | Baking test | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Volume | Texture | Colour |
| | bushels | | % | % | % | cc. | | |
| *1926* | | | | | | | | |
| 1A | 32 | 3° | 16.5 | 1.66 | 51.4 | 596 | 8 | 9 |
| B | 24 | 3° | 15.8 | 1.56 | 51.2 | 500 | 7 | 9 |
| 2A | 31 | 4 | 15.4 | 1.62 | 51.0 | 520 | 8 | 9 |
| B | 40 | 3° | 15.0 | 1.46 | 52.8 | 554 | 8 | 9 |
| 3A | 34 | 3° | 14.5 | 1.47 | 53.4 | 519 | 8 | 9 |
| B | 33 | 3° | 15.1 | 1.46 | 52.6 | 580 | 8 | 9 |
| *1927* | | | | | | | | |
| 4A | 56 | 3° | 15.4 | — | 54.2 | 512 | 9 | 9 |
| B | 49 | 3° | 13.9 | — | 54.2 | 520 | 8 | 10 |
| 5A | 34 | 3° | 15.6 | — | 53.8 | 564 | 9 | 9 |
| B | 40 | 3° | 14.4 | — | 53.6 | 509 | 9 | 9 |

The results obtained from the five pairs of duplicate plots included i table 4 show variations typical of the entire series. There is usually a marke difference in the yield of duplicates. In general the grade is the same fo both plots. More or less marked variations are observed in protein, ash, flou yield and loaf volume. Apparently the differences in quality may be just a great when the yields are approximately equal as when they vary b several bushels. In general the texture and colour of the loaves baked fro the duplicate samples are similar. There are a few discrepancies shown in th table, but since the scoring of bread is a matter of personal judgment rathe than of precise measurement and the differences do not exceed one point they cannot be regarded as important. The table shows that several of th important factors in wheat quality are noticeably influenced by the soi conditions.

## Relation to Experimental Technique

The results of these experiments emphasize the necessity of using prope technique in the growing and sampling of material for wheat quality studies The choice of a reasonably uniform piece of ground is the first essential Possibly the large variations found in the Raymond series and the compara tively uniform results of the Edmonton series may be regarded as the tw

extremes likely to be met with in wheat grown on level blocks of land. Even in the latter case, however, it was obviously necessary to adopt some method of obviating the effects of soil heterogeneity.

Ordinary methods of plot replication, as used in yield tests, should be satisfactory also for quality tests. If it is desired to ascertain the variability of the soil, it will be necessary to make separate quality tests of the crop from each plot, since it has been shown that variations in yield and quality do not parallel one another. The protein test will probably be sufficient for this purpose. When the object is to compare the quality of different varieties, or that resulting from different soil treatments, it will usually be satisfactory, assuming adequate plot replication, to test composite samples carefully made up from all the replicates. When a solid block or field of one variety is to be sampled, the sample should be composed of numerous sheaves well-distributed over the entire area. If this material is to be used in experiments which involve comparison of a number of samples treated differently before threshing, the bulk should be divided by splitting each sheaf into the required number of parts. In case an entire crop or cutting is to be used, the same object may be achieved by assigning sheaves in rotation, in the order in which they fall from the binder, to different lots.

Whatever method of replication or sampling is used, however, it is unsafe to attach importance to small differences in quality unless these can be proven statistically to be significant.

## Summary

1. Experiments are reported which show that wide variations may occur in the quality of wheat grown in replicate plots, and that variations in yield and quality are not necessarily related..
2. On an experimental block at Raymond, Alberta, which was level and uniform in appearance, the protein content of twelve varieties of wheat grown in quadruplicate plots showed a spread between replicates ranging from 2.2 to 4.9 per cent in individual varieties. The coefficient of variation in protein content of varieties ranged from 8.2 to 15.1 and in percentage of vitreous kernels from 12.8 to 160.7. The differences due to soil heterogeneity were greater than the differences due to variety.
3. In a similar experiment at Edmonton, Alberta, the spread in protein content of thirteen varieties ranged only from 0.3 to 1.6 per cent and its coefficient of variation from 1.0 to 5.8. These comparatively small variations are, however, greater than those due to the combined effect of errors in sampling and in determining protein content, as shown by results of analyses made in four laboratories.
4. A third series of samples, grown at Lethbridge, Alberta, showed again the unreliability of quality tests based on samples from single plots.
5. Suitable methods for eliminating the effect of soil variation are suggested.

## LITERATURE CITED

1. Hayes, H. K. and Garber, R. J. Breeding Crop Plants. McGraw-Hill Book Co. p. 81, 1927.
2. Newton, R., Cook, W. H. and Malloch, J. G. Hardness of the wheat kernel in relation to protein content. *Scientific Agriculture, 8,* 205-219. 1927.

# THE EFFECT OF SOIL TYPE ON THE AVAILABILITY OF FINELY GROUND ROCK PHOSPHATE*.

P. O. Ripley†
*Dominion Experimental Station, Lennoxville, P.Q.*

[Received for publication January 30, 1930].

There appears to be a renewal of interest in the use of rock phosphate as a carrier of phosphorus. This is probably due, in part at least, to the marketing of a product which is claimed to be very finely ground. Although there are on record results from the use of raw rock phosphate in many experiments it occurred to us that there is need for further study on the comparative availability and efficiency of the finely ground material and superphosphate when applied to widely different soil types.

Certain investigators have stressed the importance of fineness of grinding of rock phosphate as it affects the availability of its phosphorus to plants.

Ellis (*7*) states "the beneficial results of ground raw rock phosphate depend very largely upon the fineness of grinding, and that at least 80 per cent should pass through 100 mesh sieve".

Christie (*5*) reported that ordinary ground rock phosphate produced crop increases equal to 49 per cent of those produced by acid phosphate. This commercial rock phosphate contained 25 per cent of material of the fineness of clay. When ground so that it contained 75 per cent of material of this degree of fineness, the crop increase was raised to 56 per cent of that from acid phosphate.

Rousseaux (*14*) showed that rock phosphate pulverized to colloidal fineness was considerably inferior to superphosphate on rye and potatoes.

Brioux and Tardy (*3*) found that so-called colloidal phosphate had little beneficial influence on grain crops while on root crops it gave practically as good results as superphosphate.

## Plan of Experiment

In the investigations, barley was used as the test crop and the plants were grown in the greenhouse. Barley was chosen in the light of conclusions arrived at by several investigators, showing that it responds fairly readily to treatments of both superphosphate and rock phosphate.

Four soil types were utilized in these studies:

Miami loam, a friable, granular, workable soil, under cultivation, light brown in colour with a medium content of organic matter. This soil has medium absorptive powers for both moisture and soil nutrients, normal fertility with a tendency to run low in phosphorus.

Brookston heavy silt loam, a soil with a higher colloidal clay content than Miami which has a tendency to make it become cloddy if worked when too wet. This tendency is offset to a large extent, however, by a high percentage of organic matter, and also calcium, and it usually breaks down to a

*A thesis submitted to the Graduate School of the Michigan State College of Agriculture in partial fulfillment of the requirements for the Degree of Master of Science.
†Assistant to Superintendent.

condition of good tilth. The colour is almost black when wet but on drying becomes dark gray.

Wisner silt loam, is a soil similar to Brookston in many respects but more friable, more loamy and better general tilth. It is dark gray in colour and often contains as high as 20 per cent calcium carbonate. Fragments of fresh water shells are commonly seen throughout the soil. The organic matter content is relatively high, about 5 per cent, and the fertility is similar to that of Brookston. The pH value is 8.20. This soil occurs to a limited extent in the marsh prairie section of the lowland lake bed of Tuscola County in the "thumb" region of Michigan.

Warsaw loam is a dark brown or black prairie soil, granular, friable, and of good tilth generally. It is well drained, with medium absorptive power for both water and nutrients. It is relatively high in organic matter, the pH value is 5.47 and it responds to lime and complete fertilizers. It occurs in several small areas in southwestern Michigan.

The phosphorus carriers under test were superphosphate, containing 20 per cent of available $P_2O_5$, and rock phosphate. Two grades of rock phosphate were used, one of very finely ground material all of which would pass through a 100 mesh sieve, and 99.2 per cent through 200 mesh. The other sample was less finely ground, all of which would pass through a 100 mesh sieve but only 89.3 per cent through 200 mesh. Each grade of rock phosphate contained less than 2 per cent of colloidal material as tested by the hydrometer method of Bouyoucos (*2*).

The soils were prepared for the containers by passing them through a 4 mesh sieve. Muriate of potash and nitrate of soda were dissolved in water and the solution added to the soil at a rate equivalent to 100 pounds of each fertilizer, per 2,000,000 pounds of soil. The whole mass was then turned several times and again sifted to insure thorough mixing. During the mixing process water was added in sufficient amount to bring the soil to optimum moisture content which was estimated to be from about 11 to 18 per cent for these soils. Distilled water was used in all cases.

After mixing, 8 kilograms of soil were weighed into 2-gallon glazed, earthenware containers. Varying amounts of phosphate fertilizers were weighed for each treatment and mixed with the soil. The mixing was again done by turning and sifting to make sure that the phosphate was evenly and equally distributed through the soil. The grain was planted in a circle running two inches inside the circumference of the pots. Ample seed was sown so that after germination the plants could be thinned to 22 plants per pot. Water was applied as required, and the pots and soil weighed once a week in order to keep the same optimum moisture content on all treatments.

The first set of treatments was on Miami soil. It was necessary to use the plants from two pots of each treatment in the first cut when the growth was small, in order to secure enough sap for phosphorus analysis. Each of the five pots used for the four different cuttings received the same treatment. The first growth was harvested 19 days after the plants appeared above the ground, the second at 35 days, the third 53 days and the fourth at 71 days.

The cutting was done as nearly as possible at the same hour of the day each time so that any effect of light would be approximately the same at each sampling. McCool (*10*) showed that the amount of phosphorus in the plant varies with the time of day at which samples for analysis are taken. The samples were cut and placed in a desiccator over a 10 per cent solution of sulphuric acid to prevent drying out of the tissue before yields could be determined. The green material was weighed and a sample was retained for dry matter and moisture determinations. Phosphorus analysis was made on the expressed sap of the plants. Investigations by McCool (*10, 11*) and McCool and Weldon (*12*) show that analysis of the cell sap of plants gives reasonably accurate indications of the difference in phosphorus assimilation by crops grown on soil on which various applications of fertilizer have been made. The method of extracting the juice is described by McCool and Weldon (*12*) and the phosphorus was determined by the Coeruleomolybdate reaction of Deniges as modified by Atkins (*1*).

The second set-up consisted of four phosphate treatments and a check on each of the three soil types, Brookston, Warsaw and Wisner. The green crop was harvested at three different periods namely: at 20 days, 38 days and 52 days, after growth had started. As on the Miami soil, growth was taken from two pots at the first cutting, in order to have enough material for analysis. Yields were taken on the two pots separately and averaged.

An attempt was made to determine the amount of water soluble phosphorus in the soil in order to discover whether any correlation existed between it and the growth of plants, and the assimilation of phosphorus by them. The method outlined by Atkins (*1*) was tried and it seemed impossible to centrifuge the soil water solutions clear enough to allow for the comparing of the blue coloration due to the reaction with phosphorus present, with any degree of accuracy. The 1:5 extract as described by Parker and Tidmore (*13*) was also tried using the colorimetric method for phosphorus determination. With this method the solutions were perfectly clear, but only on the soils treated with superphosphate was it possible to obtain any indication of phosphorus and then in amounts so small as to make colour comparison almost impossible. The method of Spurway (*16*) was then attempted, and while there was slight indication of the presence of water soluble phosphorus, the differences were so small and the amounts so limited it was decided to abandon any further work along this line.

## Results of Experiments

The results from the first set-up on Miami soil are shown in table 1.

The most outstanding result was the consistency with which super-phosphate treatments produced higher yields and greater phosphorus content in the sap. Even the small application of 100 pounds of super-phosphate per acre produced, with one exception, (green yield and moisture content at the 71 day growth period) higher yields than the highest, 1600 pounds per acre application of rock phosphate. In every case the phosphorus content of the sap was higher on the superphosphate treated pots. Furthermore, in connection with superphosphate treatments, in each case where there was an increase in amount of fertilizer applied to the soil, there was with two excep-

tions a corresponding increase in the yield of the crop, and with one exception an increase in phosphorus content of the sap.

In almost every case the increase in yield of the crop was proportionately greater due to 100 and 200 pound applications of superphosphate, than where 400 pounds of fertilizer was applied.

On the other hand, the phosphorus content of the sap in the three early stages of growth showed a greater increase between the 200 pound and 400 pound applications than between any two of the other applications. A decrease in phosphorus content occurred on the 400 pound application at the 71 day period.

The increases from rock phosphate were not so outstanding as with superphosphate. There did, however, seem to be some stimulating effect due to rock phosphate. Considering the treatments with the medium finely ground rock phosphate, increases in the size of applications of the fertilizer were followed by very small increases in yields of the crop with comparative consistency.

Finely ground rock phosphate appeared to give no better results than the medium ground material.

The results for the second set-up on Brookston, Warsaw and Wisner soil are shown in tables 2, 3 and 4 respectively.

The effects of soil type on the availability of the phosphates as expressed in yields of barley and phosphorus content of the sap may be more readily compared in table 5.

The crop showed greater response to superphosphate treatments than to the rock phosphate, on all four types of soil, and at each of the three stages of growth, both as expressed by yield of crop, and phosphorus in the sap.

Increases in rock phosphate application were followed by reasonably consistent increases in yield, on the Miami soil only.

The Warsaw soil type was the only one on which treatments with rock phosphate were followed by increases in the phosphorus content of the sap with any degree of consistency.

The per cent of dry matter in the plant increased considerably at each successive period of growth on all soil types, while the per cent moisture decreased. This differentiation was greater on Wisner and Warsaw soil than it was on Brookston, and was greater on Brookston than on Miami.

The rate of growth was different on each soil type. Wisner produced the greatest growth, followed in order by Warsaw, Brookston and Miami.

The crop grown on the Warsaw soil in general showed a greater phosphorus content of sap than it did on any of the other soils. This was especially true of the rock phosphate treatments. Wisner soil, which yielded the greatest growth of crop showed the lowest amount of phosphorus in the sap, with the possible exception of Miami. This again applied more particularly to rock phosphate treatments.

TABLE 1. *Yield of barley and phosphorus content of expressed sap on Miami soil at four different growth periods.*

| Treatment | First growth period 19 days | | | Second growth period 35 days | | | Third growth period 53 days | | | Fourth growth period 71 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Green Weight Grams | Dry Weight Grams | Phosphorus in sap p.p.m. | Green Weight Grams | Dry Weight Grams | Phosphorus in sap p.p.m. | Green Weight Grams | Dry Weight Grams | Phosphorus in sap p.p.m. | Green Weight Grams | Dry Weight Grams | Phosphorus in sap p.p.m. |
| Medium Rock Phos. 200 lbs. | 7.26 | 0.54 | 101 | 15.88 | 1.48 | 98 | 31.33 | 3.39 | 149 | 47.43 | 6.17 | 143 |
| Medium Rock Phos. 400 lbs. | 7.34 | 0.56 | 82 | 15.58 | 1.27 | 99 | 34.93 | 3.67 | 148 | 46.14 | 5.88 | 124 |
| Medium Rock Phos. 800 lbs. | 7.58 | 0.60 | 97 | 16.04 | 1.43 | 103 | 34.15 | 2.41 | 155 | 50.61 | 6.14 | 136 |
| Medium Rock Phos. 1600 lbs. | 7.48 | 0.54 | 95 | 17.89 | 1.54 | 91 | 33.00 | 2.48 | 146 | 58.00 | 7.16 | 175 |
| Finely Gr. Rock Phos. 200 lbs. | 7.32 | 0.58 | 114 | 13.42 | 1.27 | 104 | 35.42 | 2.57 | 132 | 48.21 | 6.00 | 144 |
| Finely Gr. Rock Phos. 400 lbs. | 7.44 | 0.57 | 108 | 14.67 | 1.29 | 104 | 31.32 | 2.14 | 157 | 61.29 | 6.63 | 174 |
| Superphosphate 100 lbs. | 8.96 | 0.64 | 141 | 19.03 | 1.61 | 112 | 45.58 | 4.78 | 163 | 58.01 | 7.56 | 242 |
| Superphosphate 200 lbs. | 9.44 | 0.63 | 230 | 25.07 | 1.97 | 149 | 48.60 | 4.83 | 199 | 69.14 | 9.42 | 447 |
| Superphosphate 400 lbs. | 10.16 | 0.72 | 339 | 28.42 | 2.31 | 188 | 48.00 | 5.02 | 306 | 69.00 | 8.88 | 413 |
| Check, No Phosphate | 7.35 | 0.56 | 101 | 14.74 | 1.42 | 104 | 27.61 | 1.96 | 123 | 46.54 | 6.28 | 146 |

TABLE 2. *Yields of barley and phosphorus content of expressed sap on Brookston soil.*

| Treatment | Growth Period | Per cent dry matter | Moisture content grams | Green weight grams | Increase over check grams | Dry weight grams | Increase over check grams | Phosphorus in Sap p.p.m. | Increase over check p.p.m. |
|---|---|---|---|---|---|---|---|---|---|
| Rock Phosphate 500 lbs. | 1st period | 10.14 | 9.19 | 10.23 | 0.64 | 1.04 | 0.00 | 105 | — 8 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 10.51 | 8.65 | 9.67 | 0.08 | 1.02 | —0.02 | 102 | — 11 |
| Rock Phosphate 1500 lbs. | Feb. 22nd | 10.56 | 8.51 | 9.52 | —0.07 | 1.01 | —0.03 | 113 | 0 |
| Superphosphate 200 lbs. | 20 days | 9.88 | 14.28 | 15.85 | 6.26 | 1.57 | 0.53 | 237 | 124 |
| Check, No Phosphate | | 10.80 | 8.55 | 9.59 | | 1.04 | | 113 | |
| Rock Phosphate 500 lbs. | 2nd Period | 11.13 | 29.37 | 33.05 | 1.36 | 3.68 | 0.02 | 190 | 10 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 11.23 | 30.62 | 34.49 | 2.80 | 3.87 | 0.17 | 167 | —13 |
| Rock Phosphate 1500 lbs. | March 12th | 11.30 | 27.21 | 30.68 | —1.01 | 3.47 | —0.23 | 157 | —23 |
| Superphosphate 200 lbs. | 38 days | 11.38 | 45.05 | 50.84 | 19.15 | 5.79 | 2.09 | 327 | 147 |
| Check, No Phosphate | | 11.69 | 27.99 | 31.69 | | 3.70 | | 180 | |
| Rock Phosphate 500 lbs. | 3rd Period | 13.61 | 52.20 | 60.42 | —2.61 | 8.22 | —0.64 | 228 | 17 |
| Rock Phosphate 1000 lbs. | Feb. 2nd | 13.67 | 52.48 | 60.79 | —2.24 | 8.31 | —0.55 | 232 | 21 |
| Rock Phosphate 1500 lbs. | to Mar. 26 | 15.40 | 49.22 | 58.17 | —4.86 | 8.95 | 0.09 | 250 | 39 |
| Superphosphate 200 lbs. | 52 days | 16.33 | 56.90 | 68.00 | 4.97 | 11.10 | 2.24 | 378 | 167 |
| Check, No Phosphate | | 14.05 | 54.17 | 63.03 | | 8.86 | | 211 | |

— Denotes decrease

TABLE 3. *Yields of barley and phosphorus content of expressed sap on Warsaw soil.*

| Treatment | Growth Period | Per cent dry matter | Moisture content grams | Green weight grams | Increase over check grams | Dry weight grams | Increase over check grams | Phosphorus in Sap p.p.m. | Increase over check p.p.m. |
|---|---|---|---|---|---|---|---|---|---|
| Rock Phosphate 500 lbs. | 1st period | 10.64 | 14.74 | 16.46 | 2.16 | 1.75 | 0.22 | 126 | − 8 |
| Rock Phosphate 100 lbs. | Feb. 2nd | 10.43 | 12.56 | 14.03 | −0.28 | 1.46 | −0.07 | 141 | 7 |
| Rock Phosphate 1500 lbs. | to Feb. 22nd | 10.38 | 13.42 | 14.97 | 0.67 | 1.55 | 0.02 | 132 | − 2 |
| Superphosphate 200 lbs. | 20 days | 11.06 | 15.33 | 17.24 | 2.94 | 1.91 | 0.38 | 163 | 29 |
| Check, No Phosphate | | 10.67 | 12.77 | 14.30 | | 1.53 | | 134 | |
| Rock Phosphate 500 lbs. | 2nd period | 13.13 | 42.02 | 48.37 | 3.28 | 6.35 | 0.75 | 202 | 48 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 12.26 | 46.07 | 52.51 | 7.42 | 6.44 | 0.84 | 251 | 97 |
| Rock Phosphate 1500 lbs. | Mar. 12th | 12.20 | 45.03 | 51.29 | 6.20 | 6.26 | 0.66 | 265 | 111 |
| Superphosphate 200 lbs. | 38 days | 13.42 | 45.89 | 53.00 | 7.91 | 7.11 | 1.51 | 266 | 112 |
| Check, No Phosphate | | 12.43 | 39.49 | 45.09 | | 5.60 | | 154 | |
| Rock Phosphate 500 lbs. | 3rd period | 18.15 | 59.75 | 73.00 | −2.10 | 13.25 | 0.10 | 345 | 13 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 18.48 | 56.80 | 69.68 | −5.42 | 12.88 | −0.27 | 382 | 49 |
| Rock Phosphate 1500 lbs. | March 26 | 17.46 | 64.84 | 78.55 | 3.45 | 13.71 | 0.56 | 414 | 82 |
| Superphosphate 200 lbs. | 52 days | 18.97 | 69.00 | 85.15 | 10.05 | 16.15 | 3.00 | 482 | 150 |
| Check, No Phosphate | | 17.51 | 61.95 | 75.10 | | 13.15 | | 332 | |

− Denotes decrease

TABLE 4. *Yields of barley and phosphorus content of expressed sap on Wisner soil.*

| Treatment | Growth Period | Per cent dry matter | Moisture content grams | Green weight grams | Increase over check grams | Dry weight grams | Increase over check grams | Phosphorus in Sap p.p.m. | Increase over check p.p.m. |
|---|---|---|---|---|---|---|---|---|---|
| Rock Phosphate 500 lbs. | 1st period | 10.08 | 12.56 | 13.96 | 0.39 | 1.40 | 0.04 | 138 | 47 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 10.37 | 11.90 | 13.28 | −0.29 | 1.38 | 0.02 | 132 | 41 |
| Rock Phosphate 1500 lbs. | Feb. 22nd | 10.36 | 14.22 | 15.86 | 2.29 | 1.64 | 0.28 | 157 | 66 |
| Superphosphate 200 lbs. | 20 days | 10.71 | 15.91 | 17.82 | 4.25 | 1.91 | 0.55 | 173 | 72 |
| Check, No Phosphate | | 10.03 | 12.21 | 13.57 | | 1.36 | | 91 | |
| Rock Phosphate 500 lbs. | 2nd period | 13.52 | 48.58 | 56.17 | 1.77 | 7.59 | 0.47 | 147 | 14 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 12.31 | 52.51 | 59.99 | 5.59 | 7.38 | 0.26 | 149 | 16 |
| Rock Phosphate 1500 lbs. | Mar. 12th | 12.65 | 52.46 | 60.06 | 5.66 | 7.60 | 0.48 | 139 | 6 |
| Superphosphate 200 lbs. | 38 days | 13.35 | 56.49 | 65.19 | 10.79 | 8.70 | 1.58 | 278 | 145 |
| Check, No Phosphate | | 13.09 | 47.28 | 54.40 | | 7.12 | | 133 | |
| Rock Phosphate 500 lbs. | 3rd period | 16.76 | 79.72 | 95.77 | 8.97 | 16.05 | −0.16 | 186 | 11 |
| Rock Phosphate 1000 lbs. | Feb. 2nd to | 17.46 | 72.23 | 87.51 | 0.71 | 15.28 | −0.93 | 189 | 14 |
| Rock Phosphate 1500 lbs. | Mar 26th | 17.03 | 69.82 | 84.15 | −1.65 | 14.33 | −1.88 | 199 | 24 |
| Superphosphate 200 lbs. | 52 days | 18.91 | 81.41 | 100.39 | 13.59 | 18.98 | 2.77 | 352 | 177 |
| Check, No Phosphate | | 18.67 | 70.59 | 86.80 | | 16.21 | | 175 | |

− Denotes decrease

TABLE 5. *Yields of barley and phosphorus content of expressed sap on four soil types.*

| Treatment | Miami | | | | Brookston | | | | Warsaw | | | | Wisner | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Green weight grams | Dry weight grams | Moisture content grams | Phos. p.p.m. | Green weight grams | Dry weight grams | Moisture content grams | Phos. p.p.m. | Green weight grams | Dry weight grams | Moisture content grams | Phos. p.p.m. | Green weight grams | Dry weight grams | Moisture content grams | Phos. p.p.m. |
| First Period | | | | | | | | | | | | | | | | |
| Rock Phosphate 500 lbs. | 7.34 | 0.56 | 6.78 | 82 | 10.23 | 1.04 | 9.19 | 105 | 16.46 | 1.75 | 14.71 | 126 | 13.96 | 1.40 | 12.56 | 138 |
| Rock Phosphate 1000 lbs. | 7.58 | 0.60 | 6.98 | 97 | 9.67 | 1.02 | 8.65 | 102 | 14.02 | 1.46 | 12.56 | 141 | 13.28 | 1.38 | 11.90 | 132 |
| Rock Phosphate 1500 lbs. | 7.48 | 0.54 | 6.94 | 95 | 9.52 | 1.01 | 8.51 | 113 | 14.92 | 1.55 | 13.42 | 132 | 15.86 | 1.64 | 14.22 | 157 |
| Superphosphate 200 lbs. | 9.44 | 0.63 | 8.81 | 230 | 15.85 | 1.57 | 14.28 | 237 | 17.24 | 1.91 | 15.33 | 163 | 17.82 | 1.91 | 15.91 | 173 |
| Check | 7.35 | 0.56 | 6.79 | 101 | 9.59 | 1.04 | 8.55 | 113 | 14.30 | 1.53 | 12.77 | 134 | 13.57 | 1.36 | 12.21 | 91 |
| Second Period | | | | | | | | | | | | | | | | |
| Rock Phosphate 500 lbs. | 15.58 | 1.27 | 14.31 | 99 | 33.05 | 3.68 | 29.37 | 190 | 48.37 | 6.35 | 42.02 | 202 | 56.17 | 7.59 | 48.58 | 147 |
| Rock Phosphate 1000 lbs. | 16.04 | 1.43 | 14.61 | 103 | 34.49 | 3.87 | 30.62 | 167 | 52.51 | 6.44 | 46.07 | 251 | 59.99 | 7.38 | 52.61 | 149 |
| Rock Phosphate 1500 lbs. | 17.89 | 1.54 | 16.35 | 91 | 30.68 | 3.47 | 27.21 | 157 | 51.29 | 6.26 | 45.03 | 265 | 60.06 | 7.60 | 52.46 | 139 |
| Superphosphate 200 lbs. | 25.07 | 1.97 | 23.10 | 149 | 50.84 | 5.79 | 45.05 | 327 | 53.00 | 7.11 | 45.89 | 266 | 65.19 | 8.70 | 56.49 | 278 |
| Check | 14.74 | 1.42 | 13.32 | 104 | 31.69 | 3.70 | 27.99 | 180 | 45.09 | 5.60 | 39.49 | 154 | 54.40 | 7.12 | 47.28 | 133 |
| Third Period | | | | | | | | | | | | | | | | |
| Rock Phosphate 500 lbs. | 34.93 | 3.67 | 31.26 | 148 | 60.42 | 8.22 | 52.20 | 288 | 73.00 | 13.25 | 59.75 | 345 | 95.77 | 16.05 | 79.72 | 186 |
| Rock Phosphate 1000 lbs. | 34.15 | 2.41 | 31.74 | 155 | 60.79 | 8.31 | 52.48 | 232 | 69.68 | 12.88 | 56.80 | 382 | 87.51 | 15.28 | 72.23 | 189 |
| Rock Phosphate 1500 lbs. | 33.00 | 2.48 | 30.52 | 146 | 58.17 | 8.95 | 49.22 | 250 | 78.55 | 13.71 | 64.84 | 414 | 84.15 | 14.33 | 69.82 | 199 |
| Superphosphate 200 lbs. | 48.60 | 4.83 | 43.77 | 199 | 68.00 | 11.10 | 56.90 | 378 | 85.15 | 16.15 | 69.00 | 482 | 100.39 | 18.98 | 81.41 | 352 |
| Check | 27.61 | 1.96 | 25.65 | 123 | 63.03 | 8.86 | 54.17 | 211 | 75.10 | 13.15 | 61.95 | 332 | 86.80 | 16.21 | 70.59 | 175 |

## Discussion

In regard to the apparent impossibility of detecting water soluble phosphorus in soil extracts, it would seem logical to assume that the phosphorus applied was in some way fixed by the soil, or rendered insoluble in water. If this is true it may be necessary to add large quantities of phosphorus before it would be posible to secure any in water extracts. It would be necessary to satisfy the force, whatever it may be, which attracts the phosphorus and when this saturation point was reached there would be an excess which would remain in solution. This assumption is borne out by the work of Crawley (*6*) who found that the soil fixed as high as 99.66 per cent of the soluble phosphorus applied. Hendrick (*8*) also showed that the phosphorus in several tons of superphosphate per acre was completely fixed by the soil. Burd (*4*) stated "a water extract may be regarded as only an indicator of the general magnitudes of the solutes present and not as the equivalent of soil solutions". It would seem that plants are capable of assimilating phosphorus in some other way than in water solution. Kossovitsch (*9*) demonstrated that plant roots themselves and not the nutrient solution were responsible for obtaining phosphorus from phosphorite. It may not be assuming too much to suggest that plants can obtain phosphorus from solutions so dilute that the methods used will not detect its presence.

The greater increase in yield between 100 and 200 pound applications than between 200 and 400 pound treatments of superphosphate on Miami soil might be taken to indicate that somewhere between 200 and 400 pounds is the maximum amount to apply to this soil type for profitable returns. The fact that the pohsphorus in the sap continued to increase in practically the same proportion for each treatment while the yield increase dropped at the heavier amount, would tend to show that the rate of phosphorus intake is not in direct proportion to the growth of the plants. This fact is also demonstrated in case of Wisner soil which gave the highest yield of crop and the lowest phosphorus content of sap. This relation was also demonstrated by McCool and Weldon (*12*) who found that the percentage of phosphorus in the sap increased rapidly and appeared to be a linear function of the amount of fertilizer applied, whereas the green weight of the plants responded in different degrees to different treatments, reached a point of maximum increase and then a decrease occurred. It would seem logical to assume that as plant growth becomes more extensive the phosphorus is removed from the sap and used in the building up of tissue, thus the phosphorus becomes less concentrated in the sap. As growth slows up less phosphorus is used in building up tissue and more accumulates in the sap.

The fact that the phosphorus in the sap dropped at the 71 day period on the 400 pound superphosphate treatment was possibly due to some physiological reaction within the plant. In the later stages of growth many changes may take place in connection with the translocation of nutrients in the sap. Burd (*4*) reported a migration of nutrients from the leaves and stems of barley to the heads and roots at the time when the heads were forming.

LIBRARY
PURDUE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION

That fineness of grinding in rock phosphate does not render it any more available under conditions such as obtained in these experiments, seems to be fairly well demonstrated. It might be possible that over a period of time the finer material might become available to a greater extent than the coarser material. One of the chief values of phosphorus, however, lies in its ability to stimulate the early growth in the plant and in this respect rock phosphate whether fine or coarse is decidedly inferior to superphosphate. These results are similar to those reported by Rousseaux (*14*) who showed that rock phosphate pulverized to colloidal fineness was considerably inferior to superphosphate. Brioux and Tardy (*3*) found that so-called colloidal phosphate had little beneficial influence on grain crops. Christie (*5*) and Ellis (*7*), however, claim that finely ground rock phosphate is much more available than the coarser material.

It seems significant that Miami, a slightly acid soil, was the only type on which consistent increases in yields were obtained from increases in rock phosphate treatments. It is also true that Warsaw, a decidedly acid soil, was the only one which showed increases in phosphorus content of sap with increases in rock phosphate applied. It would seem to correspond with other investigations that rock phosphate is rendered more soluble by acid soils. Truog (*17*) and Spurway (*15*) found this to be true. The fact that yields did not increase in the Warsaw soil might be due to the fact that such high acidity had a toxic effect on the plant. In other words the very factor which assists in rendering the phosphorus more available to the plant, may be one which is detrimental in some other respect. In the case of the Miami soil the reverse is true. Although increases in growth were observed, the increases in phosphorus were low in all cases, and decreases are seen on the 19 and 35 day periods. This may be due to the fact that the acidity is not harmful to the plant and good growth is maintained. It is probably true also that the acidity being less pronounced does not affect the availability of the phosphate to the same extent as in the case of the Warsaw soil. This makes two factors working against high phosphorus accumulations in the sap, namely the fact that the phosphorus is being used extensively in building up plant tissue and secondly the acidity is so weak as to act rather sparingly as a factor in the dissolving process.

## Summary

1. Barley was grown in the greenhouse on four types of soil treated with varying amounts of finely ground rock phosphate and superphosphate. Yields of crops were recorded as well as phosphorus content of the expressed sap.

2. Phosphorus in finely ground rock phosphate under the conditions of the experiment was decidedly inferior to superphosphate. Higher yields of crops and higher phosphorus content of sap were observed where superphosphate was applied at 100 pounds per acre than where treatments of finely ground rock phosphate as high as 1600 pounds per acre were applied.

3. Finely ground rock phosphate, 99.2 per cent of which would pass through a 200 mesh sieve, appeared to give no better response in crop growth

than less finely ground rock phosphate, only 89.3 per cent of which would pass through a 200 mesh sieve.

4. Higher yields were obtained on Wisner silt loam with a pH of 8.20 than on Warsaw loam with pH of 5.47. Brookston heavy silt loam with a pH of 7.21 was third in crop yield followed by Miami loam with a pH of 6.19.

5. The phosphorus content of the plant sap was higher in the plants grown on Warsaw soil than on any of the other three soil types. This was especially true with regard to rock phosphate treatments.

6. Plants seem to have power to absorb phosphorus from soil in which water soluble phosphorus cannot be detected by several well known methods of analysis.

7. The growth of plants does not appear to be in direct proportion to the accumulation of phosphorus in the sap.

## Acknowledgements

To Dr. M. M. McCool the writer wishes to express his gratitude for advice during the experimental work and for reading and criticizing the manuscript. Acknowledgement is also made to M. D. Weldon and other members of the Soils Department for suggestions and assistance.

## Literature Cited

1. Atkins, W. R. G. "The rapid determination of available phosphate in soil by the Coeruleomolybdate reaction of Deniges". Jour. Agric. Sci. *14*: 192-197, 1924.
2. Bouyoucos, G. J. "Directions for determining the colloidal material of soils by the hydrometer method." Sci. *66*: (1896) 16-17. 1927.
3. Brioux, C. and Tardy, A. "Test of phosphatic fertilizer". Ann. Sci. Agron. Franc et Etrang. *41*: 312-319. 1924. Cited from Exp. Sta. Rec. *52*: 623, 1925.
4. Burd, J. S. "Rate of absorption of soil constituents at successive stages of plant growth". Jour. Agr. Res. *18*: 51-72, 1919-20.
5. Christie, G. I. "Pot tests of fertilizers". Ind. St. Rpt. p. 54, 1923.
6. Crawley, J. T. "Fixation of phosphorus in the soil". Jour. Amer. Chem. Soc. *24*: 1114-1119, 1902.
7. Ellis, A. F. "Finely ground rock phosphate". New Zealand Jour. Agric. *22*: 335-340, 1921. Cited from Exp. Sta. Rec. *56*: 21, 1922.
8. Hendrick, J. "Drainage investigations at Aberdeen". Scot. Jour. Agric. *7*: 8-18, 1924.
9. Kossovitsch, P. S. "Plant phosphorite and soil according to experiments in the agricultural laboratory of St. Petersburg". Zhur. Opiutn. Agron. (Russ. Jr. Exp. Landro.) *10*: 782-842, 1909. Cited from Marias, Soil Sci. *13*: 355, 1922.
10. McCool, M. M. "Relation of soil to plant cell sap". Mich. Agric. Exp. Sta. Quar. Bul. *9*: 60-64, 1926.
11. ———— "The effect of soil fertilization on the moisture content, density, heat of wetting, and phosphorus content of the cell sap of plants". Proc. Int. Soil Sci. Congress 449-453, 1927.
12. ————and Weldon, M. D. "The effect of soil type and fertilization on the composition of the expressed sap of plants". Jour. Amer. Soc. Agron. *20*: 778-792, 1928
13. Parker, F. W. and Tidmore, J. W. "The influence of lime and phosphate fertilizers on the phosphorus content of the soil solution and of soil extracts". Soil Sci. *21*: 425-441, 1926.
14. Rousseaux, E. "Comparative tests of phosphatic fertilizers". Ann. Sci. Agron. Franc et Etrang. *41*: 241-250, 1924. Cited from Exp. Sta. Rec. *52*: 323, 1925.
15. Spurway, C. H. "The effect of fertilizer salts treatments on the composition of soil extracts". Mich. Agric. College Tech. Bul. 45, 1919.
16. ———— "Test soils for water soluble phosphorus". Mich. Agric. Exp. Sta. Quar. Bul. *9*: 64-67, 1926.
17. Truog, E. "The utilization of phosphates by agricultural crops". Wis. Agric. Exp. Sta. Res. Bul. *41*: 1916.

# A METHOD OF DETERMINING THE VARIATIONS IN THE VERTEBRAL COLUMN OF THE LIVE PIG*

A. M. SHAW†
*University of Saskatchewan, Saskatoon, Sask.*
[Received for publication March 24, 1930].

In a previous paper ‡ the writer established the fact that the number of ribs in the pig varies at least from 13 to 17 pairs inclusive. Also that the variation in the vertebrae is confined to the thoracic and lumbar regions of the vertebral column.

These conclusions were arrived at entirely by post-mortem methods. In order to carry out further investigational work with regard to the inheritance of rib and vertebrae variation, it became necessary to devise some method of determining accurately the rib number in the live animal. Several methods were tried. In the first place, efforts were made to count by hand the ribs of pigs of all ages and conditions, but without complete success. It is possible to count the ribs of a new-born pig, but not with absolute accuracy. Several mechanical contrivances were tested, but proved to be unsatisfactory. It was then decided to try the X-ray, the use of which, up to this time, had been delayed in the hope that some less expensive method might be found, the machine finally adopted being one of the standard diagnostic type. The factors used in radiographing were 36 inch distance (tube to plate), 50 milliamperes of current, time one-twentieth of a second and voltage to suit the various sizes varying from a 3 inch spark gap to a 5 inch spark gap.

Pigs of different ages were radiographed, but it soon became apparent that the best age, all things considered, was when they were from six to eight days old. At this age, it is possible to radiograph four pigs on one 14 by 17 inch plate, only one pig being radiographed at a time, the balance of the plate being covered with a lead-lined rubber mat. The pig is held firmly on its back, in position on the plate which is directly under the X-ray tube, by two attendants, one of whom grasps the forelegs and draws them forward one on each side of the head while the other grasps the hind legs and draws them backward and slightly downward. The attendants should be provided with lead-lined gloves to avoid any danger from undue exposure to the X-rays. By holding the pig in this position, it is easily controlled and seldom struggles. Radiographs of pigs in many other positions were taken, but none proved to be as satisfactory as the position outlined. The exposure required was only one-twentieth of a second per pig which meant that large numbers could be dealt with on a comparatively short time.

In order to keep accurate records, the following system of marking was used. At birth, the young pigs were ear tagged with specially made metal tags which could be inserted in the ears of very young pigs. The numbers of all pigs were then, together with all particulars regarding the sire and dam, entered in a record book. At six to eight days, the pigs were radiographed in rotation, litter by litter, and each plate was marked by placing Roman numerals made of lead on it at the end where the first exposure was made.

*Contribution from the Department of Animal Husbandry, University of Saskatchewan.
†Professor of Animal Husbandry.
‡Shaw—"Variations in the skeletal structure of the pig" *Scientific Agriculture*, Vol. X, No. 1, Sept., 1929.

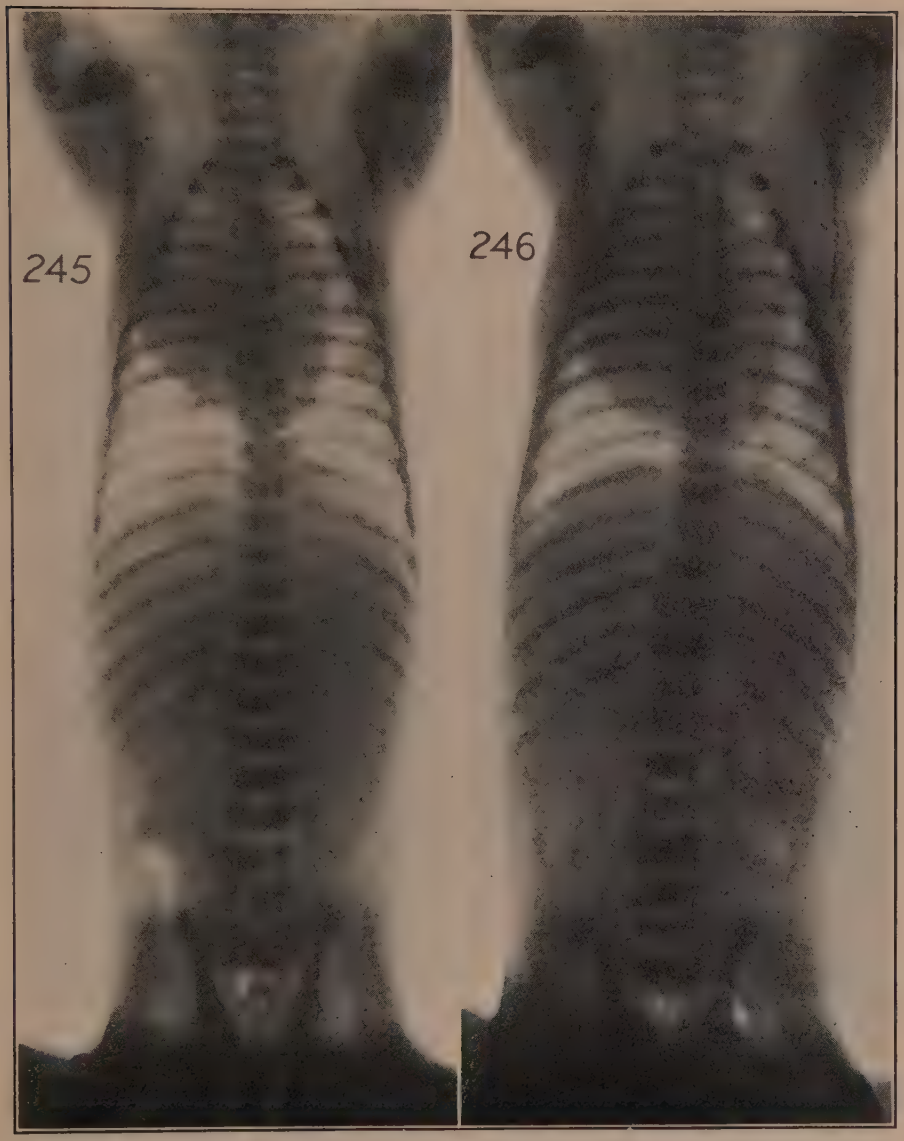



Figure 1. Radiograph of two pigs taken at age of 7 days. Left has 16 and right has 17 pairs of ribs.

By this means, a number in the form of a Roman numeral became a part of each picture, and, by having the number in the same position each time, all danger of error which might easily occur during the developing process was entirely eliminated.

As soon as the plates could be developed, the rib and vertebrae counts were made, the films filed and each pig was then permanently marked by tattooing its respective number in the ear. As the variations in the vertebral column occur in only two regions *, namely, the thoracic and lumbar, it was decided to use three figures in each number, the first two figures indicating

*Shaw—"Variations in the skeletal structure of the pig." *Scientific Agriculture*, Vol. X, No. 1, Sept., 1929.

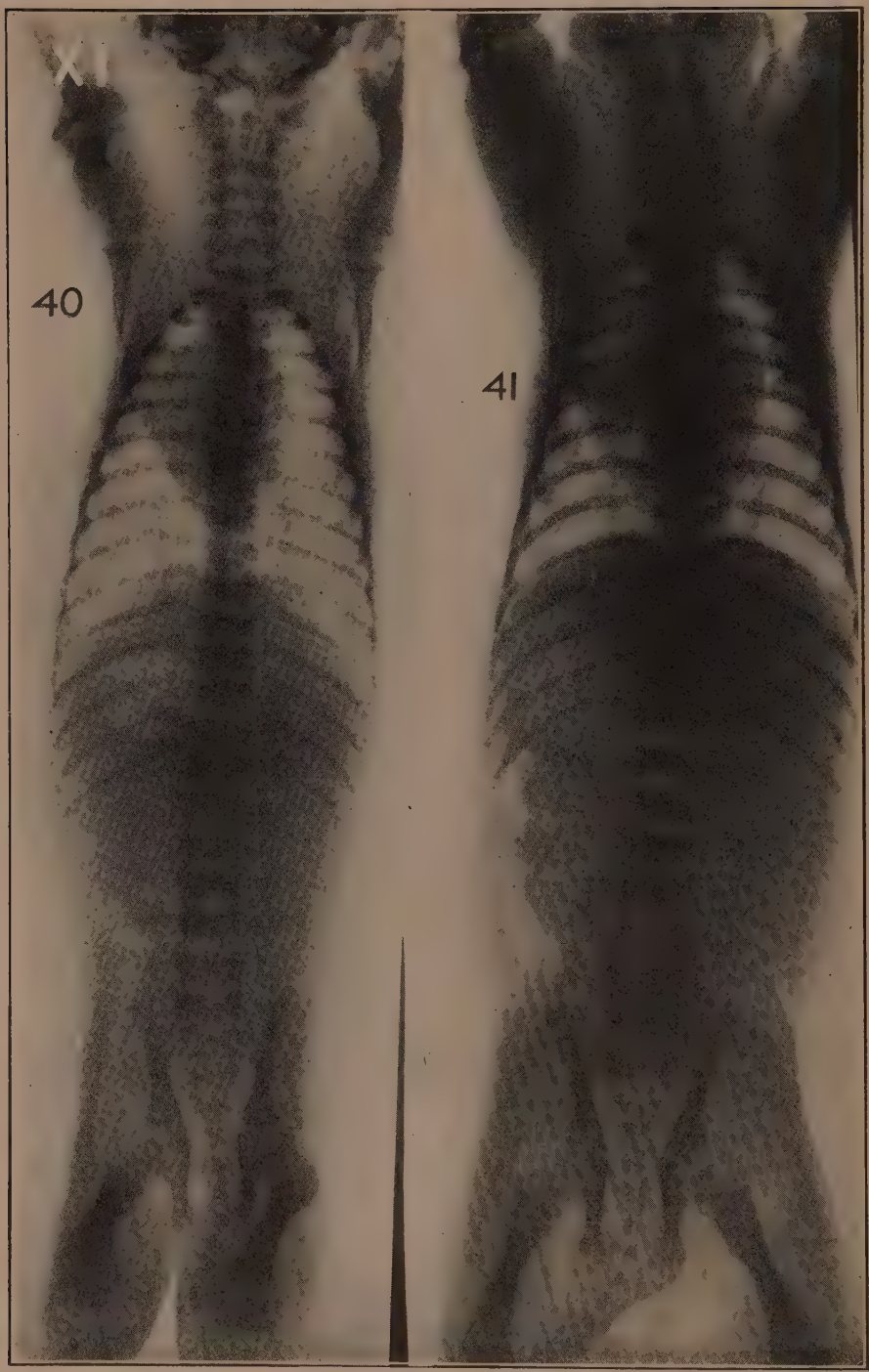



Figure 2. Radiograph of four pigs showing three with 15 pairs and one with 14 pairs of ribs taken on one 14 x 17 inch plate. At the upper left hand corner is shown the plate number (XI) while the individual pig numbers (40, 41, 42, 43) appear commencing at the upper left hand side.

To ensure clearer reproduction the plate was divided, the other half appearing on the opposite page.

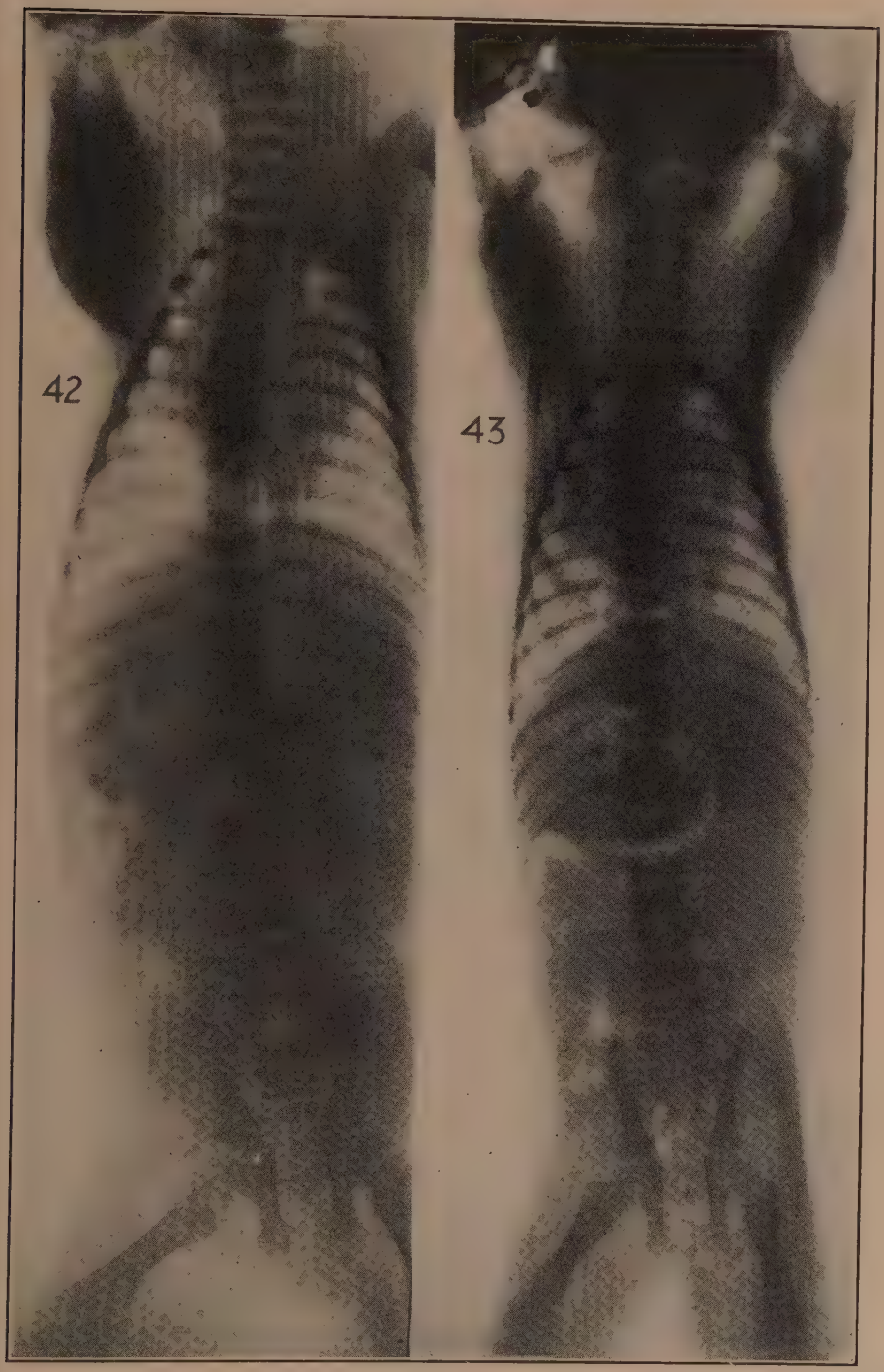

42
43

Figure 3. These Yorkshire sows are approximately the same age (11 months), are of the same breeding and were raised under similar conditions. The sow on the left has 17 pairs of ribs, and is No. 245 in Figure 1. The sow on the right has 14 pairs of ribs and is No. 41 in Figure 2. The difference in length and growthiness is even more evident than it appears to be in the photograph.

the number of ribs or thoracic vertebrae, and the last figure indicating the number of lumbar vertebrae.

The figure 146 was tattooed in the ear of all pigs possessing 14 pairs of ribs and 6 lumbar vertebrae, and 147 in the ear of all pigs possessing 14 pairs of ribs and 7 lumbar vertebrae. Other numbers used were 156, 157, 166, 167, 175 and 176. In this way, all groups as well as individual pigs were definitely marked. However, as a double precaution, the pig was again tagged, giving each classification a separate series of numbers. The tattoo method proved to be quite satisfactory as a permanent means of identification, but the additional ear-tag made it easier to identify quickly any particular pig.

In all, some 294 pigs were radiographed. These were all bred and raised on the University of Saskatchewan Farm and consisted mostly of purebred Yorkshires, together with some Tamworths and Berkshires.

The reason for using such large numbers in the investigation was to insure, if possible, large groups of pigs possessing all the different vertebral variations so that suitable animals might be selected for breeding purposes. The entire 294 were sired by five different boars so that among the various groups, it was possible to select animals of widely different strains as well as others closely related. After the various groups required for breeding purposes had been selected, the balance of the pigs under observation were finished for market and disposed of locally. These were found, upon post-mortem examination, to check perfectly with the original radiographs.

A large number of matings have already been made, these matings being so arranged that all variations in both the thoracic and the lumbar regions are included, although, for the most part, they are as follows: fourteens are being mated with fourteens, fifteens with fifteens, sixteens with sixteens, and seventeens with seventeens. All pigs in the litters from the above matings will, at the proper time, be radiographed in the hope that some light may be thrown upon the inheritance of vertebral variations.

It would appear that the use of the X-ray is entirely practical for work of this kind. No detrimental effects have been noted by us as a result of

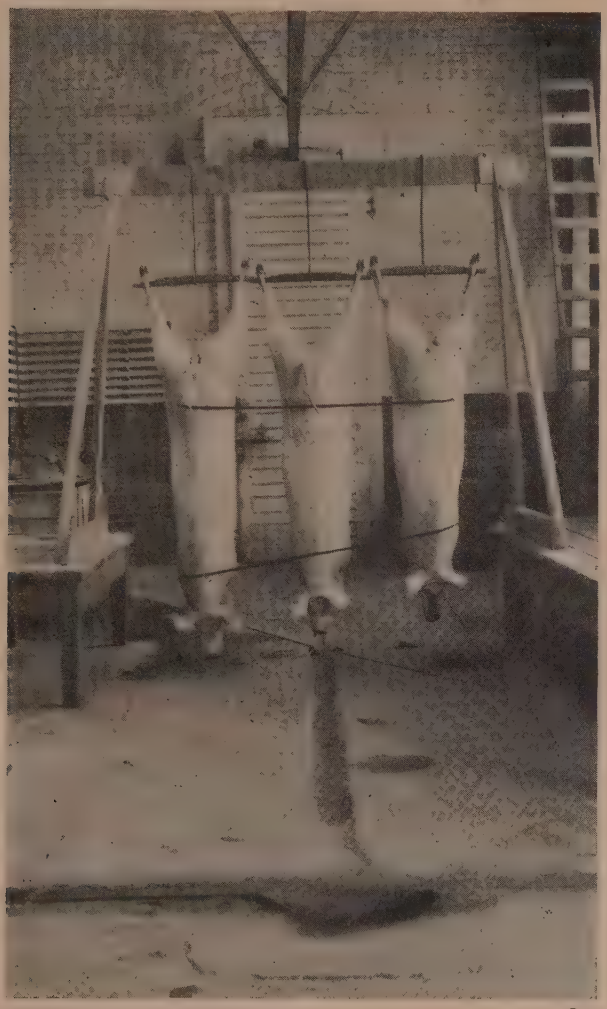


Figure 4. Photograph indicating that length of carcass is closely associated with the variation in rib number. From left to right, the rib numbers are 16-,-15 and 14 pairs respectively. The carcasses are from pigs raised and fed under similar conditions. They were 6½ months of age when killed. The carcasses are hanging level. The upper tape is placed exactly upon the last lumbar vertebrae in each carcass while the lower tape is placed on the vertebrae to which the first pair of ribs is attached. The fact that the upper tape is horizontal and that the lower tape runs diagonally indicates that the increased length occurs in the thoracic and lumbar region or, in other words, between the shoulder and the ham.

its use and, when large numbers are radiographed at a time, the cost is not excessive.

## Acknowledgements

The writer wishes to acknowledge the great assistance rendered by the following in material aid and advice in prosecution of the work here reported, W. G. Kirk, Instructor in Animal Husbandry, University of Saskatchewan, J. W. G. MacEwan, Assistant Professor of Animal Husbandry, University of Saskatchewan, E. L. Harrington, Professor of Physics, University of Saskatchewan and Earl E. Shepley, Roentgenologist and Physiotherapist, Saskatoon, Sask.

# NOUVELLE TABLE D'ALIMENTATION POUR LES VACHES LAITIERES

J. R. Proulx
*Ecole d'Agriculture, Ste-Anne de la Pocatière*

De toutes les divisions de la science agricole, il n'y en a peut-être pas qui ont nécessité autant de patientes recherches que celle de l'alimentation du bétail. Cette science exige en effet de la part des chercheurs des connaissances approfondies de chimie alimentaire et de physiologie animale. Les expériences dans ce domaine sont généralement longues et difficiles à contrôler. Grâce cependant aux découvertes du siècle dernier, l'alimentation est aujourd'hui une chose passée dans le domaine des précisions scientifiques.

Malheureusement bien peu des conclusions trouvées par les expérimentateurs ont jusqu'ici été mises à la portée du cultivateur. Ceci est dû au fait que l'alimentation rationelle du bétail est en elle-même compliquée et que, règle générale, le cultivateur n'a pas les connaissances nécessaires pour interpréter les données présentées dans les traités d'alimentation même élémentaires.

C'est la raison qui nous a fait chercher un moyen qui permettrait au cultivateur de balancer convenablement la ration de ses vaches sans l'obliger à des calculs longs et difficiles pour lui. Nous croyons que la table d'alimentation décrite dans cet article remplira ce but et nous la présentons comme un guide permettant d'éviter au moins les erreurs les plus grossières.

Le dispositif tel que construit permet de balancer les rations d'après la quantité de protéines exigée. Cette méthode est généralement satisfaisante pourvu que les mélanges de moulées recommandés contiennent environ 75% de principes nutritifs totaux et au moins 4% de matières grasses. On sait en effet que les matières hydrocarbonées sont moins exposées à manquer que la protéine si les animaux reçoivent une quantité suffisante de fourrages. La grande simplicité de ce dispositif permet à une personne relativement peu instruite de préparer rapidement et facilement un mélange de moulées qui répondra aux exigences de la moyenne des vaches d'un troupeau suivant la qualité du fourrage servi et la quantité et la qualité du lait produit.

Cette table d'alimentation se compose de deux disques superposés d'inégales grandeurs réunis à leur centre par un rivet et coopérant ensemble pour fournir les indications désirées. Comme on pourra le constater en jetant un regard sur la figure II, la partie marginale du grand disque porte des indicateurs du pourcentage de gras du lait en vue de l'ajustement de l'instrument, tandis que sa partie centrale comprend une série de chiffres représentant par parties la composition des divers mélanges. Ces chiffres sont disposés de façon qu'ils apparaissent par une ouverture allongée pratiquée sur le petit disque (Fig. I). Sur les bords de cette ouverture ou fenêtre a été inscrit le nom des divers concentrés communément employés dans l'alimentation des vaches laitières. De plus, les noms des divers fourrages ont été inscrits à une distance égale sur des rayons du petit disque. Ces fourrages sont associés deux par deux suivant les indications suivantes: avec succulent, sans succulent, avec ou sans succulent. Le dispositif est construit de façon à ce que la composition d'un mélange de moulées apparaisse par l'ouverture

lorsque l'indicateur d'un fourrage et celui d'un pourcentage de gras sont placés vis-à-vis l'un de l'autre. Les mélanges de moulées contiennent de 10 à 24% de protéine digestible; ils sont indiqués par parties et servent à compléter la ration de fourrage servie.

Supposons par exemple que nous ayons en main du foin de trèfle et de l'ensilage de maïs pour alimenter une vache (ou un troupeau) dont le lait dose 4% de matières grasses. En ajustant l'indicateur "Foin de Trèfle, avec succulent", vis-à-vis de 4% la réponse sera la suivante:

| | |
|---|---|
| Maïs | 1 partie |
| Avoine | 3 parties |
| Son | 2 " |
| Gluten | 3 " |
| Tourteau de lin | 2 " |
| Pourcentage de protéine: | 17 |

Ce mélange peut être servi à raison de 1 lb par 3 à 4 lbs (3½ en moyenne) de lait produit suivant la condition de l'animal et le prix des concentrés tel qu'expliqué au dos de la table d'alimentation. Le dispositif indique également le pourcentage de protéine de chacun des mélanges afin que le mélange recommandé puisse être remplacé au besoin par un mélange équivalent. Cette table d'alimentation sert donc à balancer une ration soit avec des moulées mélangées à la maison, soit avec des moulées commerciales achetées toutes préparées.

Des conseils généraux quant aux quantités d'aliments à servir sont donnés au verso de la table, soit: 2 lbs. de foin par 100 lbs. de poids vif, ou bien 1 lb de foin et 3 lbs d'ensilage ou 4 lbs de racines par 100 lbs de poids vif. La quantité de concentrés conseillée est de 1 lb par 3 à 4 lbs de lait produit.

D'après la construction de cette table d'alimentation, les pourcentages suivants de protéines digestibles sont recommandés dans les divers mélanges:

TABLEAU I.—*Pourcentages de protéines recommandés par la présente table d'alimentation.*

| Foin | Pourcentage de gras du lait | | | | |
|---|---|---|---|---|---|
| | 3.5 | 4 | 4.5 | 5 | 5.5 |
| Luzerne sans succulent | 10% | 11% | 12% | 13% | 14% |
| Trèfle " " | 12 | 13 | 14 | 15 | 16 |
| Luzerne avec succulent | 14 | 15 | 16 | 17 | 18 |
| Trèfle " " | 16 | 17 | 18 | 19 | 20 |
| Mêlé, avec ou sans succulent | 18 | 19 | 20 | 21 | 22 |
| Mil " " " " | 20 | 21 | 22 | 23 | 24 |

Bien que ces pourcentages de protéine puissent paraître un peu élevés dans certains cas, ils répondent généralement bien aux exigences des normes d'alimentation de Morrison. Nous publions ci-dessous un tableau compilé d'après ces normes afin de montrer les quantités de protéines requises pour l'entretien et la production d'une vache de 1000 lbs suivant la quantité et la qualité du lait qu'elle donne.

Il s'agit maintenant de savoir si la table d'alimentation décrite dans cet article répond aux exigences du tableau ci-dessus. Si l'on suppose le cas d'une vache de 1000 lbs, alimentée avec du foin mêlé et des choux-de-Siam, elle recevra par jour: 10 lbs de foin mêlé, 40 lbs. de choux-de-Siam et des

TABLEAU II.—*Exigences en protéines d'une vache de* 1000 *lbs. suivant la quantité et la qualité du lait produit.*

| Lbs de lait produit par jour | Lbs de protéines requises par jour quand le lait dose: | | | | |
|---|---|---|---|---|---|
| | 3.5% | 4% | 4.5% | 5% | 5.5% |
| 25 | 1.92 à 2.22 | 2.05 à 2.32 | 2.12 à 2.42 | 2.20 à 2.52 | 2.30 à 2.62 |
| 30 | 2.17 - 2.53 | 2.32 - 2.65 | 2.41 - 2.77 | 2.50 - 2.89 | 2.62 - 3.01 |
| 35 | 2.41 - 2.83 | 2.59 - 2.97 | 2.69 - 3.11 | 2.80 - 3.25 | 2.94 - 3.39 |
| 40 | 2.66 - 3.14 | 2.86 - 3.30 | 2.98 - 3.46 | 3.10 - 3.62 | 3.26 - 3.78 |
| 45 | 2.90 - 3.44 | 3.13 - 3.62 | 3.26 - 3.80 | 3.40 - 3.98 | 3.58 - 4.16 |
| 50 | 3.15 - 3.75 | 3.40 - 3.95 | 3.55 - 4.15 | 3.70 - 4.35 | 3.90 - 4.55 |
| 55 | 3.39 - 4.05 | 3.67 - 4.27 | 3.83 - 4.49 | 4.00 - 4.71 | 4.22 - 4.93 |
| 60 | 3.64 - 4.36 | 3.94 - 4.60 | 4.12 - 4.84 | 4.30 - 5.08 | 4.54 - 5.32 |
| 65 | 3.88 - 4.66 | 4.21 - 4.92 | 4.40 - 5.18 | 4.60 - 5.44 | 4.86 - 5.70 |

concentrés à raison de 1 lb par 3½ de lait produit, et nous obtiendrons d'après les analyses de Henry et Morrison, le tableau suivant:

TABLEAU III.—*Recommandations de la présente table d'alimentation pour une vache de* 100 *lbs. recevant du foin mêlé, des choux-de-Siam et de la moulée.*

| Lbs de lait produit par jour. | Lbs de moulée donnée par jour. | Lbs de protéine fournies par la ration décrite ci-dessus | | | | |
|---|---|---|---|---|---|---|
| | | Lait a 3.5% | 4% | 4.5% | 5% | 5.5% |
| 25 | 7 | 2.08 | 2.16 | 2.23 | 2.30 | 2.37 |
| 30 | 8.6 | 2.34 | 2.43 | 2.52 | 2.60 | 2.69 |
| 35 | 10.0 | 2.60 | 2.70 | 2.80 | 2.90 | 3.00 |
| 40 | 11.4 | 2.85 | 2.97 | 3.08 | 3.19 | 3.31 |
| 45 | 12.8 | 3.10 | 3.23 | 3.36 | 3.49 | 3.62 |
| 50 | 14.3 | 3.37 | 3.52 | 3.66 | 3.80 | 3.94 |
| 55 | 15.7 | 3.63 | 3.78 | 3.94 | 4.10 | 4.25 |
| 60 | 17.1 | 3.88 | 4.05 | 4.22 | 4.39 | 4.56 |
| 65 | 18.5 | 4.13 | 4.31 | 4.50 | 4.68 | 4.87 |
| Pourcentage de protéine dans la moulée. | | 18 | 19 | 20 | 21 | 22 |

Si l'on compare les quantités de protéines mentionnées dans le tableau ci-dessus avec celles recommandées dans le tableau II, on voit qu'une vache donnant 25 lbs de lait à 3.5% de gras recevra la ration suivante: 10 lbs de foin mêlé, 40 lbs. de choux-de-Siam et 7 lbs d'un mélange de moulées dosant 18% de protéine. Cette ration fournira 2.08 de protéine alors que les normes d'alimentation du tableau II recommandent 1.92 à 2.22, soit 2.07 en moyenne. Le lecteur notera que toutes les quantités recommandées dans le tableau ci-dessus correspondent aux recommandation de Morrison telles que compilées dans le tableau II.

Supposons maintenant qu'au lieu de foin mêlé et de choux de Siam nous ayons du foin de trèfle et de l'ensilage de mais; Les quantités recommandées au verso du dispositif sont les suivantes: Foin, 1 lb par 100 lbs de poids vif, soit: 10 lbs. de foin de trèfle. Ensilage, 3 lbs. par 100 lbs. de poids vif, soit, 30 lbs d'ensilage. Concentrés, 1 lb par 3½ de lait produit. L'analyse en protéine des aliments plus haut mentionnés fournira le tableau suivant:

Comme dans le cas précédent, les quantités de protéines mentionnées dans ce tableau tombent en dedans des quantités minimum et maximum recommandées par les normes d'alimentation du tableau II, à l'exception des deux derniers chiffres qui varient de quelques dixièmes en moins.

TABLEAU IV.—*Recommendations de la présente table d'alimentation pour une vache de 1000 lbs. recevant du foin de trèxe, de l'ensilage de mais et de la moulée.*

| Lbs de lait produit par jour. | Lbs de moulée donnée par jour. | Lbs de protéine fournies par la ration décrite ci-dessus | | | | |
|---|---|---|---|---|---|---|
| | | Lait à 3.5% | 4% | 4.5% | 5% | 5.5% |
| 25 | 7 | 2.21 | 2.28 | 2.37 | 2.45 | 2.52 |
| 30 | 8.6 | 2.45 | 2.53 | 2.63 | 2.72 | 2.81 |
| 35 | 10 | 2.69 | 2.79 | 2.89 | 2.99 | 3.09 |
| 40 | 11.4 | 2.93 | 3.04 | 3.14 | 3.26 | 3.38 |
| 45 | 12.8 | 3.13 | 3.27 | 3.39 | 3.52 | 3.65 |
| 50 | 14.3 | 3.37 | 3.52 | 3.66 | 3.81 | 3.95 |
| 55 | 15.7 | 3.61 | 3.76 | 3.92 | 4.07 | 4.23 |
| 60 | 17.1 | 3.81 | 4.00 | 4.17 | 4.34 | 4.51 |
| 65 | 18.5 | 4.05 | 4.23 | 4.42 | 4.60 | 4.79 |
| Pourcentage de protéine dans la moulée. | | 18 | 19 | 20 | 21 | 22 |

De ce qui précède on peut conclure que la table d'alimentation déjà décrite fournit des indications assez justes pour balancer convenablement la ration d'une vache de 1000 lbs dont la production est variable en quantité et en qualité.

Etudions maintenant le cas de vaches de poids variable afin de constater si les indications de ce dispositif sont également justes lorsque le poids des animaux varie.

D'après Haecker, les quantités de protéine nécessaires à l'entretien des vaches de différents poids sont les suivantes:

| Poids de l'animal | Protéine digestible requise |
|---|---|
| 800 lbs | 0.56 |
| 900 " | 0.63 |
| 1000 " | 0.70 |
| 1100 " | 0.77 |
| 1200 " | 0.84 |

Supposons que ces vaches de poids différents aient une production individuelle de 35 lbs de lait par jour; en calculant leurs exigences pour l'entretien et la production, on obtiendra le tableau suivant:

TABLEAU V.—*Quantités de protéine requises pour des vaches de différents poids donnant 35 lbs. de lait par jour.*

| Poids des vaches Lbs | Lbs de protéines requises par jour quand le lait dose: | | | | |
|---|---|---|---|---|---|
| | 3.5% | 4% | 4.5% | 5% | 5.5% |
| 800 | 2.27 à 2.69 | 2.45 à 2.83 | 2.56 à 2.97 | 2.66 à 3.11 | 2.80 à 3.25 |
| 900 | 2.34 - 2.76 | 2.52 - 2.90 | 2.63 - 3.04 | 2.73 - 3.18 | 2.87 - 3.32 |
| 1000 | 2.41 - 2.83 | 2.59 - 2.97 | 2.69 - 3.11 | 2.80 - 3.25 | 2.94 - 3.39 |
| 1100 | 2.48 - 2.90 | 2.66 - 3.04 | 2.76 - 3.18 | 2.87 - 3.32 | 3.01 - 3.46 |
| 1200 | 2.55 - 2.97 | 2.73 - 3.11 | 2.83 - 3.25 | 2.94 - 3.39 | 3.08 - 3.53 |

Si ces vaches sont alimentées au foin de trèfle, à l'ensilage de maïs et à la moulée d'après les recommandations du présent dispositif, on se trouvera à leur fournir par jour les quantités suivantes de protéine, lesquelles sont un moyen terme entre les quantités minimum et maximum du tableau V. La quantité de fourrage sera variable tandis que la moulée sera servie à raison de 1 lb par 3½ de lait produit, soit, 10 lbs. de moulée par jour.

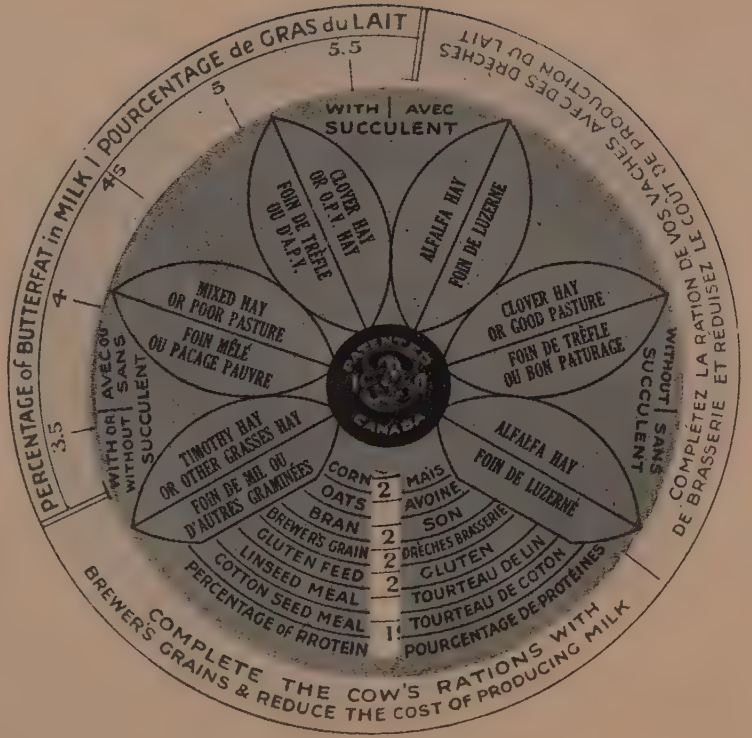



FIGURE 1.

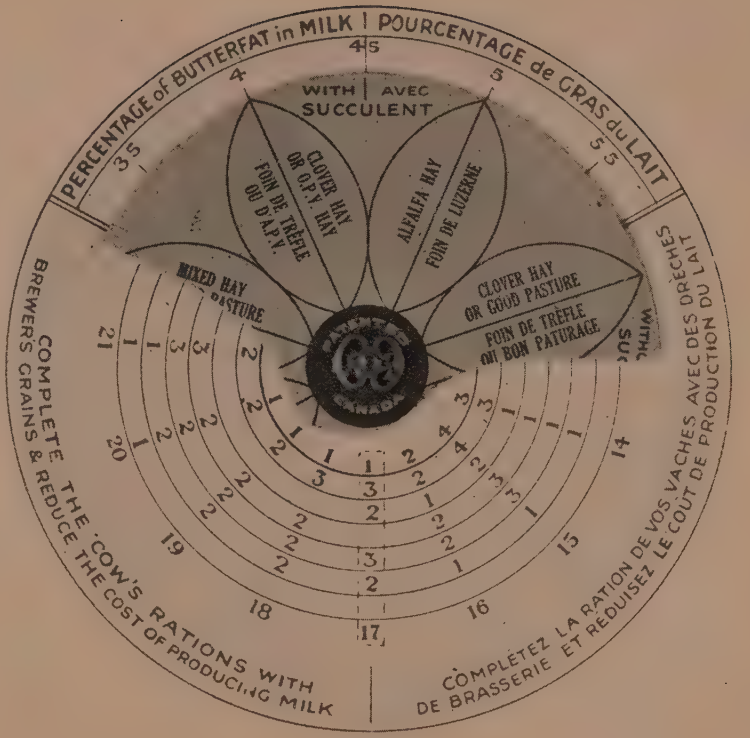



FIGURE 2.

**INSTRUCTIONS.**—Placez le nom du fourrage donné vis-à-vis du chiffre indiquant le pourcentage moyen de gras du lait et le mélange de grains à employer apparaitra par l'ouverture. Si l'on se sert d'une moulée commerciale, voir à ce qu'elle ait le pourcentage de protéines requis.

**CONCENTRES.**—Donnez 1 lb de grain par 3 à 4 lbs de lait produit suivant la condition de l'animal. Le blé et le hominy peuvent remplacer le maïs (blé d'Inde.) Les criblures renettoyées peuvent remplacer l'avoine. L'orge peut remplacer une partie de l'avoine.

**FOURRAGES.**— Sans succulent (racines ou ensilage) dans la ration, donnez 2 lbs de foin par 100 lbs de poids vif. Si les succulents sont en abondance, donnez 1 lb de foin et 3 lbs d'ensilage ou 4 lbs de racines par 100 lbs de poids vif. Si la provision de succulents est limitée, donnez 1½ de foin et 1½ d'ensilage ou 2 lbs de racines par 100 lbs. de poids vif.

**MATIERE MINERALE.**—A chaque 100 lbs de moulée, ajoutez: 1 lb de farine d'os moulus, 1 lb de pierre à chaux moulue, 1 lb de sel ordinaire.

Cette table d'alimentation a été préparée par J. R. Proulx, professeur d'élevage des animaux au Collège d'Agriculture de Ste-Anne-de-la-Pocatière, P.Q.

TABLEAU VI.—*Recommandations de la présente table d'alimentation pour des vaches de poids variable donnant 35 lbs. de lait.*

| Poids des vaches lbs | Quantité de foin lbs | Quantité d'ensilage lbs | Lbs de protéines fournies par la ration décrite ci-dessus. | | | | |
|---|---|---|---|---|---|---|---|
| | | | 3.5% | 4% | 4.5% | 5% | 5.5% |
| 800 | 8 | 24 | 2.47 | 2.57 | 2.67 | 2.77 | 2.87 |
| 900 | 9 | 27 | 2.58 | 2.68 | 2.78 | 2.88 | 2.98 |
| 1000 | 10 | 30 | 2.69 | 2.79 | 2.89 | 2.99 | 3.09 |
| 1100 | 11 | 33 | 2.80 | 2.90 | 3.00 | 3.10 | 3.20 |
| 1200 | 12 | 36 | 2.91 | 3.01 | 3.11 | 3.21 | 3.31 |
| Pourcentage de protéine dans la moulée. | | | 16 | 17 | 18 | 19 | 20 |

Si l'on compare les chiffres des tableaux V et VI on notera que pour une vache de 800 lbs dont le lait (35 lbs) dose 3.5% de gras, les normes d'alimentation du tableau V recommandent une quantité de protéine variant de 2.27 lbs à 2.69 lbs, soit, 2.48 lbs en moyenne. Le tableau VI, basé sur les recommandations du présent dispositif, conseille 2.47 lbs de protéine pour la même cas. De même, une vache de 1200 lbs donnant 35 lbs de lait dosant 5.5% de matières grasses exigera 3.08 à 3.53 lbs. de protéine pour son entretien et sa production, soit 3.30 lbs en moyenne. Cette même vache, lorsqu'on lui donne 12 lbs. de foin de trèfle, 36 lbs. d'ensilage de maïs et 10 lbs d'un mélange à 20% de protéine, reçoit 3.31 lbs de protéine, tel qu'indiqué à la dernière ligne du tableau VI. La comparaison de tous les autres chiffres amènerait des conclusions analogues.

Lorsque le cultivateur a composé un mélange de moulées convenable suivant la qualité du foin servi et la qualité moyenne du lait de son troupeau, il lui reste toujours la liberté de donner, par exemple, 1 lb de concentrés par 4 lbs de lait produit aux vaches dont le lait est le plus pauvre pendant qu'il donnera davantage à celles qui produisent un lait plus riche. D'ailleurs, lorsque toutes les vaches du troupeau appartiennent à la même race, les variations dans le pourcentage de gras du lait ne sont pas considérables.

Nous n'avons pas la prétention de présenter cette table d'alimentation comme une règle absolument rigide destinée à remplacer le jugement de l'éleveur. Même si cette publication n'avait pour seul résultat que de bien convaincre le cultivateur de la nécessité de cultiver du foin de légumineuses afin d'éviter les achat trop considérables de concentrés azotés et dispendieux, elle lui aurait déjà rendu un service appréciable.

## REUNION DE LA SECTION DE MONTREAL

La Section de Montréal s'est réunie au Cercle Universitaire de Montréal le samedi 10 mai. Une conférence remarquable du Dr. Rosell sur la mammite et ses conséquences fut vivement applaudie. Le R. P. Léopold, Directeur de l'Institut Agricole d'Oka, remercia le conférencier. La section procéda ensuite à l'élection de son bureau pour l'année 1930-1931 et des délégués de la section à la Convention annuelle à Wolfville. Furent élus: Président, M. P. N. April; Vice-Président, M. L. Therrien; Secrétaire, M.P.H. Vézina; Délégués à la Convention: MM. April, Therrien, Vézina; Lefèvre. Plusieurs motions furent passées que les délégués auront mission de présenter à la Convention.

Une autre motion fut également passée félicitant le R. P. Léopold de sa récente nomination par le Gouvernement français au grade de Chevalier de l'Ordre du Mérite Agricole.

## DIXIEME CONVENTION ANNUELLE DE LA C.S.T.A.

La dixième convention annuelle de la C.S.T.A. se tiendra a Wolfville, Nouvelle Ecosse, du 23 au 26 juin. Un programme détaillé aura été reçu par les membres avant ce numéro de la Revue. Voici l'essentiel des arrangements pris.

Ceux qui se rendront a Wolfville par le train pourront prendre soit le C.P.R. jusqu'à St. Jean, N.B., soit le C.N.R. et changer à Truro. On conseille a ceux qui s'y rendront en automobile de prendre la route no 2 et de passer par Rivière-du-Loup, Edmundston et la vallée de la rivière St. Jean. Le groupe du Nouveau Brunswick organise un voyage guidé à travers cette province, qui partira de Madawaska Inn, Edmundston, N.B., le samedi 21 juin a 1 heure p.m. Coucher à Woodstock, départ le lendemain pour St. Jean. Le bateau quittera St. Jean pour Digby, N.E., le lundi matin, 23 juin à 7 heures 15 a.m. Ceux qui désirent participer à cette excursion à travers le Nouveau Brunswick sont priés d'en avertir à l'avance M. Stanley Wood, Ministère de l'Agriculture, Fredericton, N.B., indiquant le numéro de la machine, le nombre de passagers, et les chambres désirées à l'hôtel à Woodstock et à St. Jean s'il y a lieu.

La convention se tiendra a Acadia University, Wolfville. On est prié de s'incrire aussitôt arrivé, à la suite de quoi une chambres sera assignée à chacun. Le coût de la pension à l'Université du 23 juin a midi au 26 juin après-midi sera comme suit: deux par chambre, lits simples, $5.00 par personne; chambres simples, $6.00 par personne. Les visiteurs pourront acheter des tickets de repas séparés au prix de $0.50 l'un. Il y aura en plus des frais d'enregistrement qui seront comme suit: membres des Provinces Maritimes, $3.00; autres membres, $2.00; non membres, $3.00. Les dames ne paieront pas de droit d'inscription.

La section de l'Ile du Prince Edouard organise une visite de l'Ile les 27 et 28 juin. Les voitures seront laissées à Cape Tormentine, le voyage à Charlottetown se faisant par chemin de fer et la visite de l'ile par automobiles mises à la disposition des visiteurs par des organisations locales. Comme il y a une nuit à passer à l'hôtel, ceux qui désirent prendre part à cette excursion sont priés d'en avertir le plus tôt possible M. B. F. Tinney, Dominion Experimental Station, Charlottetown, P.E.I., en lui donnant les renseignements qui lui permettront de retenir les chambres nécessaires à l'hôtel, etc.

De toutes raçons, ceux qui désirent assister à la convention sont priés d'en avertir le plus tôt possible soit le bureau central à Ottawa, soit le secrétaire français, soit M. W. V. Longley, Agricultural College, Truro, N.S. Pour ceux qui désirent se rendre en Nouvelle Ecosse dans leur propre automobile, il est particulièrement important de notifier avant le 8 juin M. Longley en indiquant la marque et la carosserie de la voiture. Le bateau qui fait le service de St. Jean à Digby ne peut en effet prendre que de 15 à 25 automobiles par passage suivant leur grosseur, et il est indispensable de réserver à l'avance l'espace nécessaire. Des guides et des mécaniciens seront fournis par le Ministère de la Voirie de la Nouvelle Ecosse.

Pour tous renseignements supplémentaires, s'adresser soit au bureau central a Ottawa, soit au secrétaire français à Montréal.

## BOOK REVIEW

LIVE STOCK AND POULTRY DISEASES—By Dr. W. A. Billings, Assistant Professor of Veterinary Medicine, University of Minnesota, Minneapolis, Minn., U.S.A. (Rural Science Series, McMillan, 1930. Price $4.00).

This work, as the author indicates in his preface, is not intended as a veterinary encyclopedia, it is not intended as a reference for the professional, nor to obviate the necessity of competent veterinary assistance on the part of the stockman. Rather the attempt is made to supply the reader with up-to-date accurate information concerning diseases commonly met with on the farm, in words understandable and as far as possible non-technical. A review of the book indicates that the author's attempt along these lines has been singularly successful.

It is concise, up-to-date, entirely readable and easily understood. The unique features of this work, as compared to others treating with the same subject, are, first, the emphasis placed all the way through on disease prevention as made possible by correct methods of breeding, feeding, housing and management. In this very connection, the putting into effect of the counsel in Chapter 1,—"How Sanitation May Prevent Live Stock Diseases",—would alone return the price of the book one hundred fold on the majority of farms. Secondly, the author has refreshingly commmon sense views on live stock feeding, particularly with reference to mineral mixtures, condiments, special feeding mixtures of all kinds and fads generally, such as we have not seen so well expressed elsewhere.

Aside from the treatment of actual disease and injury, the most modern methods of control of animal parasites receive special attention. Diseases and affections of sheep and swine receive just as thorough attention as do those of the larger animals. Another valuable feature is that, referring to each class of stock, a chapter is devoted to the period of parturition, covering practical hygienic and disease control methods, particularly important at this time. Infectious diseases are in each class of stock classified and treated separately. The chapter on "Calving Time and Breeding Troubles" should be of particular value to the dairyman.

Generally speaking, this book is thoroughly comprehensive for the purpose, yet concise, well illustrated, easily read and understood and very evidently based primarily on sound practical common sense knowledge of the nutrition, production, reproduction and care and management of farm live stock. It looks like an up-to-date and reliable friend to the stockman.

G. B. R.

## CONCERNING THE C.S.T.A.

### Notes and News

Robert Newton (McGill '12) and Georges Bouchard (Laval '08) have each been elected a Fellow of the Royal Society of Canada.

W. H. Fairfield (Colorado '94) has received the honorary degree of LL.D. from the University of Alberta.

Arthur Gibson, Dominion Entomologist, is leaving on June 5th, for London, England, to attend the Third Entomological Conference which is being held by the Imperial Bureau of Entomology.

B. W. Morton (Toronto '21) has changed his address to R. R. 2, Stouffville, Ont.

S. O. Hillerud (Alberta '20) has been appointed Provincial Apiarist for the Province of Alberta.

G. W. Challenger (British Columbia '25) formerly District Agriculturist at Kamloops, B.C., and Secretary-Treasurer of the British Columbia Stock Breeders' Association, has received the appointment of Assistant Live Stock Commissioner under the British Columbia Department of Agriculture.

K. A. Harrison (Toronto '24), who has been taking graduate work in the Botany Department at the University of Toronto under a T. Eaton Company scholarship, has now resumed his duties as Assistant Plant Pathologist at the Dominion Laboratory of Plant Pathology, Kentville, N.S.

E. R. Bewell (Manitoba '14) has changed his address to 1724-17th Avenue, New Westminster, B.C.

A. H. Martin (Toronto '24), for the past three years Agricultural Representative for Renfrew County, Ont., has been appointed Assistant Director, Crops Co-operation and Markets Branch, Ontario Department of Agriculture, with headquarters at Toronto, Ont.

E. W. Atkins (Manitoba '28) is now on the staff of the Hudson's Bay Company at Edmonton, Alta.

J. H. Bruneau (Montreal '28) who, for the past two years has been Assistant County Agriculturist at Plessisville, P.Q., is now County Agriculturist for Pontiac County (Division No. 2), with headquarters at Fort Coulonge, P. Q.

Arthur Dumais (Laval '17), formerly District Representative under the Saskatchewan Department of Agriculture, is now on the staff of the Dominion Seed Branch at Saskatoon, Sask.

Trueman Stevenson (Toronto '12) has accepted a position as Research Assistant in Forage Crop Investigations in the Field Husbandry Department of the University of Saskatchewan, Saskatoon, Sask.

E. E. Eisenhauer (Saskatchewan '18) has changed his address to 422-8th Street South, Lethbridge, Alta.

R. W. Stuckey (McGill '28) has recently been awarded the Associateship of the Imperial College of Tropical Agriculture (A.I.C.T.A.) of Trinidad B.W.I. He is at present with the Department of Agriculture, Kampala,

Uganda, British East Africa, but his permanent address is Spring Cot, Crowborough, Sussex, England.

R. F. V. Cooper (McGill '26) has changed his address to Encargado, Laboratorio de Fitopatologfa, Cinco Saltus, F.C.S. Argentina, South America.

D. F. Putnam (Toronto '27), who has been taking graduate work at Macdonald College, P.Q., has received an appointment as Plant Disease Investigator at the Dominion Laboratory of Plant Pathology, Kentville, N.S.

A. B. Banks (Toronto '26), formerly Agricultural Representative for Colchester County, N.S., has been transferred to Cumberland County, with headquarters at Amherst, N.S.

K. C. Thorneloe (British Columbia '28) who is at present taking graduate work in the Dairy Industry Department of the Iowa State College, has received a position on the staff of the Dairy Department of the Manitoba Agricultural College. He will take up his new duties on July 1st, 1930.

N. B. McMaster (McGill '29) has been awarded a bursary by the National Research Council.

R. H. Smith (McGill '24) has changed his address to 2050 Marlowe Avenue, Montreal, P. Q.

C. C. Main (Toronto '11), formerly Agricultural Representative under the Ontario Department of Agriculture, has joined the staff of the Manufacturers Life Insurance Co., with headquarters at Cayuga, Ont.

## Applications for Membership

The following applications for regular membership have been received since May 1, 1930:

Bird, W. J. (Toronto, 1920, B.S.A.) Truro, N.S.

Cram, W. W. (Alberta, 1929, B.Sc.A.) Indian Head, Sask.

Evans, O. C. (Toronto, 1917, B.S.A.) Port Haney, B.C.

Hastings, R. J. (Toronto, 1922, B.S.A.) Saanichton, B.C.

Jones, Walter (Wales, 1921, B..Sc., California, 1929, M.S.) Saanichton, B.C.

Ledingham, G. A. (Saskatchewan, 1927, B.Sc., 1928 M.Sc.) Northport, Wash. U.S.A.

## The Tenth Annual Convention

The Maritime branches extend an invitation to all members of the C.S.T.A. to attend the first Maritime Annual Convention and spend the tenth anniversary of the Scciety "Down by the Sea." Acadia University, the headquarters for the Convention is "The College on the Hill," set amongst the apple orchards of The Annapolis Valley and near the dyked lands bordering Minas Basin. Close at hand is Grand Pré, the scene of Longfellow's immortal poem, "Evangeline." Blomidon will be included in the places visited and many other points of historic interest.

New Brunswick, Nova Scotia and Prince Edward Island are all noted for their scenic beauty, their home-like farms, their potato fields, apple orchards and dairy herds. "The Island", also known as the "Garden of the Gulf," will be visited in the tour of the Maritimes.

Four prominent agriculturists from the United States have consented to give two lectures each (one to an open meeting and one to a group meeting): Dr. J. H. Gourlay, Chief, Department of Horticulture, Ohio Agricultural Experiment Station, Wooster, Ohio, Dr. L. J. Stadler, Associate Professor of Field Crops, College of Agriculture, University of Missouri, Columbia, Mo., Dr. G. Bohstedt, Professor of Animal Husbandry, University of Wisconsin, Madison, Wis., and Dr. G. F. Warren, Professor of Agricultural Economics and Farm Management, Cornell University, Ithaca, N.Y. Members will also have an opportunity of enjoying one or probably two lectures by Mr. D. Akenhead, Chief Officer, Imperial Bureau of Fruit Production, East Malling, England.

The convention programme has already been distributed and the attention of all members is directed to the importance of making the necessary reservations as early as possible for the various trips, ferry and hotel accommodation, etc., requested in the programme.

## Vacancies in the Dominion Department of Agriculture

The Civil Service at Ottawa is advertising the following vacancies in the Dominion Department of Agriculture. Applications should be addressed to the Secretary of the Commission:

*Agricultural Economist.* Initial salary $2,640 per annum up to a maximum of $2,880. To be located at Ottawa. Applications should be filed not later than June 5, 1930.

*Experimental Farm Assistant.* Initial salary $1,920 per annum up to a maximum of $2,220. To be located at Kentville, N.S. Applications should be filed not later than June 5, 1930.

*Live Stock Promoter.* Initial salary $1,620 per annum up to a maximum of $1,920. To be located in Prince Edward Island. Applications must be filed not later than June 16, 1930.

*Head Poultryman.* Initial salary $1,320 per annum up to a maximum of $1,620. To be located in Alberta. Applications must be filed not later than June 11, 1930.

## C.S.T.A. Employment Bureau

As announced in a previous issue of *Scientific Agriculture*, the C.S.T.A. is now offering space in the journal for the announcement of openings in the field of professional agriculture, as a form of assistance to employing institutions seeking qualified candidates for vacancies. Key numbers are being used for each vacancy in order to prevent direct approaches being made to the institution or firm concerned. Members of the Society who wish to make application for the position described below should communicate with the C.S.T.A. Employment Bureau, P. O. Box 625, Ottawa, Ont.

No. 104. Manufacturer of farm and poultry equipment requires an agricultural college graduate with practical farm and sales experience. Salary to be arranged.